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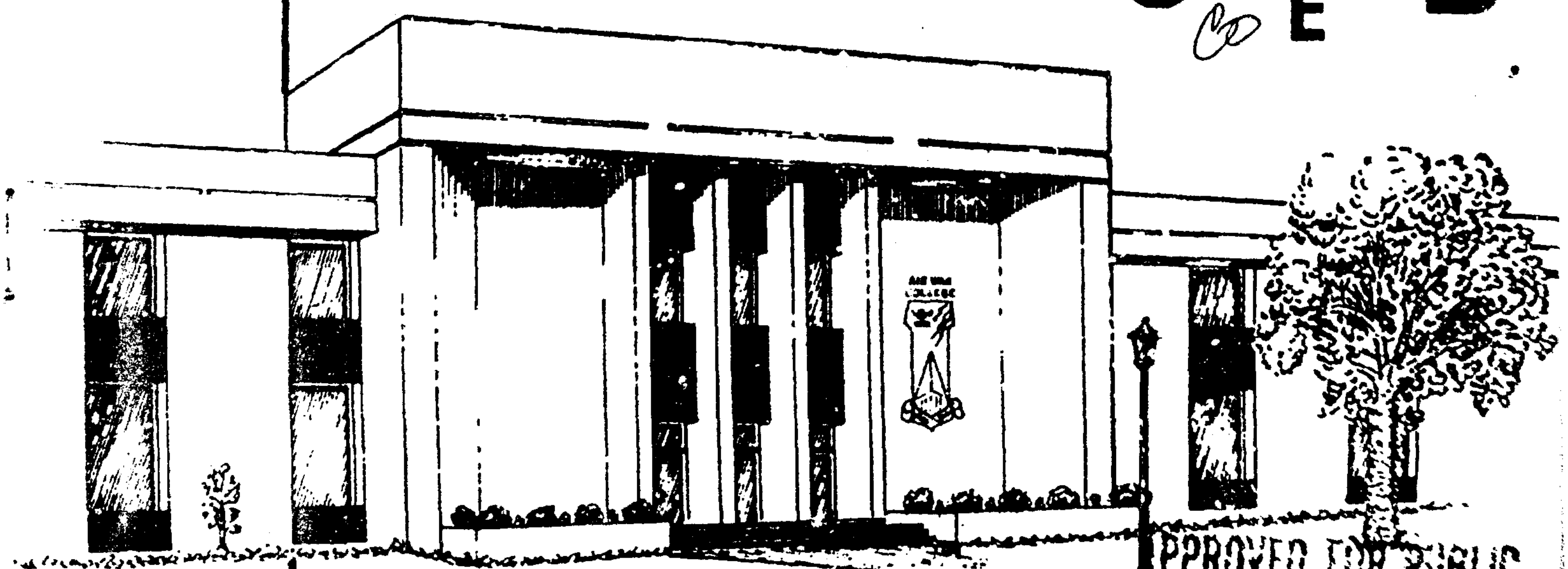
PROBABLE IMPACTS OF SPACE OPERATIONS
ON AIR FORCE CIVIL ENGINEERING

LIEUTENANT COLONEL JOHN W. MOGGE, JR

1989



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PROBABLE IMPACTS OF SPACE OPERATIONS ON AIR FORCE CIVIL ENGINEERING

by

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Lieutenant Colonel, USAF

A Defense Analytical Study Submitted to the Faculty
in Fulfillment of the Curriculum Requirement

Advisor: Colonel Eric Sunberg

Maxwell Air Force Base, Alabama

May 1989

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EXECUTIVE SUMMARY

Author: John W. Mogge, Jr., Lieutenant Colonel, USAF
Title: Probable Impacts of Space Operations on Air Force Civil Engineering

Remarks on vision as the bridge from today's space programs and systems to tomorrow's space reality introduce the study. From this an analytical model and framework are presented which form the major contents of the study. The chapter on Policy presents research into the changes of space policy and a discussion on where national space policy is focused. The military imperatives in space in relation to space policy is a major theme of this chapter which concludes that current space policy is revolutionary in nature. The next two chapters on Organizations and Activities and Technology and Systems present research into the DoD and NASA and their recent changes related to space. Numerous space related programs focusing on transportation systems, space control, space weapons and power are analyzed with respect to their potential to effect change. Revolutionary characteristics are present in many of these programs and activities. Chapter five presents a discussion of support concepts, specifically space logistics, engineering and space facilities. Evolutionary and revolutionary potentials are drawn from these topics. Chapter six is an assessment of two hundred linear relationships and thirty-three nonlinear relationships drawn from the previous chapters. This assessment yields highly evolutionary bounds for ground based civil engineering missions and revolutionary bounds for space based civil engineering missions of the future. A brief word picture of the year 2010 concludes this chapter. The last chapter, Future Considerations, presents an approach for civil engineers to take, in relation to developing their space support missions. The approach has four basic tenets: visualization of space as the basis of global power, focusing attention on the linkages between space policy and technology, acceptance of a bias for action in space, and, the last, the normalization of space in civil engineering.

BIOGRAPHICAL SKETCH

Lieutenant Colonel John W. Mogge, Jr. (BA, MA Architecture, University of Florida) is a registered architect in the State of Florida. He has served as Center Architect, Armament Division, Eglin AFB, FL; as Chief Engineer, 52nd Civil Engineering Squadron (CES), Spangdahlem Air Base, Germany; as Assistant Professor of Engineering Management, School of Civil Engineering, Air Force Institute of Technology, Wright-Patterson AFB, OH; and as Executive Officer, Deputy Chief of Staff Engineering and Services, HQ USAFE, Ramstein Air Base Germany. His most recent assignments have been as Civil Engineer Squadron Commander for the 7020th CES at RAF Fairford United Kingdom, and the 8th CES, Kunsan Air Base, Korea. He is a graduate of the Air War College, Class of 1989.

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CHAPTER I
INTRODUCTION

VISION

Today's vision can be tomorrow's reality. The bridge that takes us from visionary pursuits to realistic capabilities can be identified if one analytically studies the components of one's vision and systematically reassembles them in such a way that their influencing and controlling factors are brought to light and better understood.

One of the most pressing areas for understanding how that bridge connects our vision of space today with the reality of space tomorrow is in the broad area of Space Logistics and, its related component, Air Force Civil Engineering. In documenting this need, the Deputy Director of Air Force Engineering and Services has asked for a study which theoretically constructs how and when such a bridge may be built.[1] With the aid of such a path to tomorrow, the impact of space on Air Force Civil Engineering can be assessed. It follows then, that a concerned leadership may be better able to formulate policy, create plans and develop programs which are proactive in nature vice reactive.[2]

This study has been undertaken to provide a separate analysis and assessment of the impact of space on future civil engineering missions. Parallel to this study, the Readiness Technical Analysis Group (RTAG) under the leadership of Mr. Norman D. Falk, at The University of New Mexico is also conducting a similar study as a service contract for the USAF. Readers of this study should contact the Plans Division, HQ USAF/LEEX, to obtain a copy of the

RTAG study. At the time of this writing, the RTAG is pursuing a similar analytical methodology as was used in this study.

FRAMEWORK

Current literature concerning space can be grouped in many ways. In cataloging information for this study 10 subject areas formed natural groupings of the information. The 10 areas are:

1) policy and related matters of the utility of space, and the military imperatives of space;
2) avant-garde efforts within DoD and the commercialization of space;
3) plans, studies, and activities of the National Aeronautical and Space Administration (NASA);
4) the Strategic Defense System (SDS) and the Strategic Defense Initiative Office (SDIO);
5) space transportation systems;
6) space control and space warfare;
7) the National Aerospace Plane (NASP);
8) space construction;
9) the military man in space (MMIS); and
10) space logistics.

These subject areas provide evidence which can be synthesized to generate predicatory analysis that characterize the future of space as evolutionary, revolutionary, or perhaps even radical. For the purpose of this study, evolutionary change is defined as change occurring from the momentum of current trends, when a condition reaches a maximum tolerance, or through change in awareness or knowledge. Revolutionary change is defined as change occurring as a result of abrupt significant events.

Radical change is defined as change occurring as a result of total abolition of institutions, systems, and activities as known today in a short time increment. The utility of characterizing change comes to play in analyzing the interrelationships of the 10 subject areas.

One way to better understand the impact of space on civil engineering is to establish the potential change as a function of past events. For purposes of illustration the Ground Launched Cruise Missile (GLCM) program in Europe will be used. The civil engineering responsibilities for the GLCM program included the advocacy, planning, design, and construction of five main operating bases over a 6 year period. Following the completion of initial facilities, operation, and maintenance activities were to be assumed. The overall program called for facilities unlike any others constructed in the Air Force, the establishment of squadrons to operate and maintain them and readiness operations unlike conventional bases. While this all sounds somewhat revolutionary, it was in fact an evolutionary change with a modest impact on civil engineering in the theater. In assessing this impact one need only to look at the broad policy issues concerning the program, the organizations, and activities of the units involved, the technologies and systems used and the support concepts. Suffice it to say, while there was indeed impact, the civil engineering function at those bases and in the United States Air Force in Europe (USAFE) did not dramatically or even significantly alter its missions to accommodate the change.

The same analytical model used for the GLCM example above will be used in this study about space. A diagram at this point will serve to illustrate the outcomes (Figure 1).

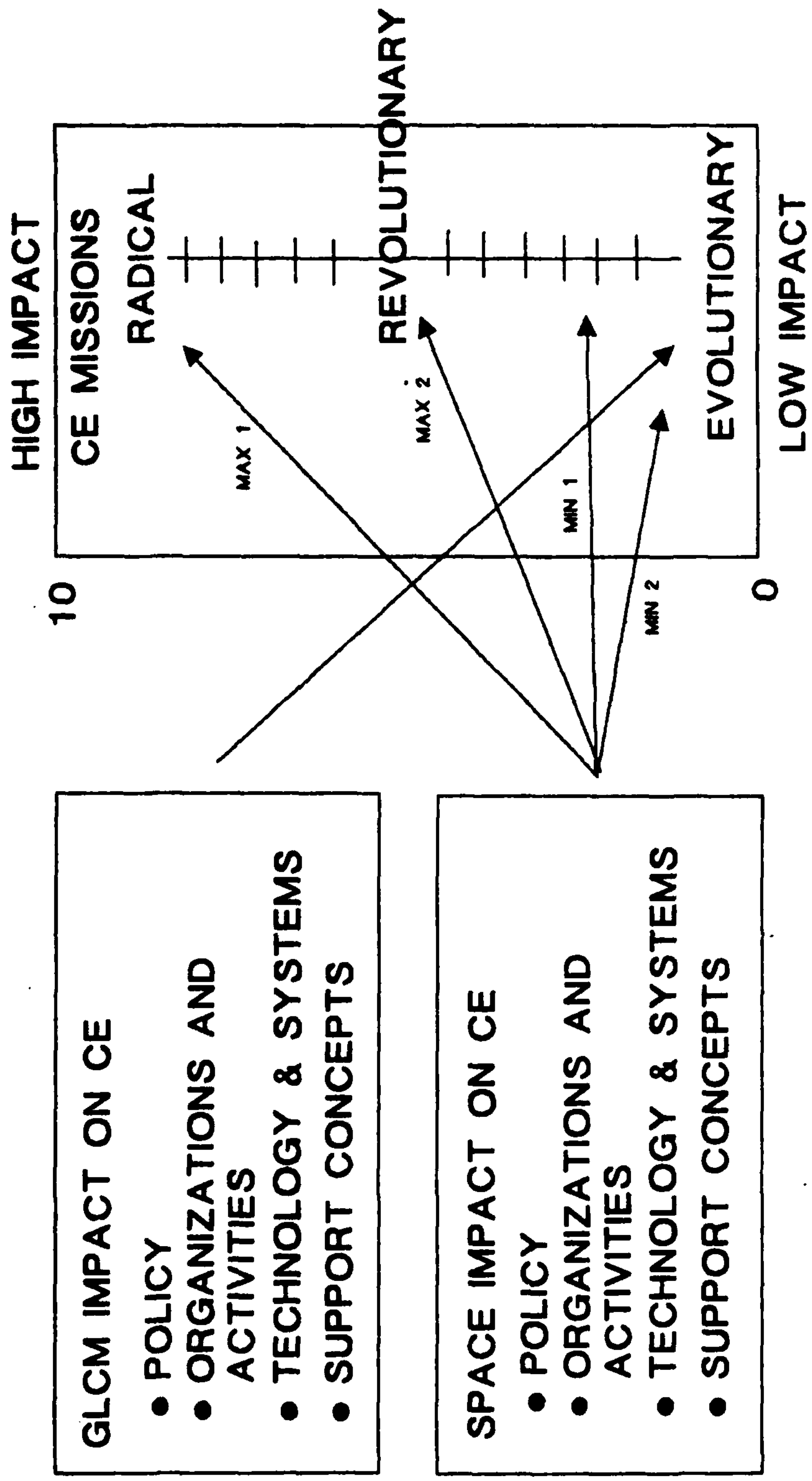

Figure 1. Analytical Model

The GLCM program is characterized as an evolutionary change. As a mobile tactical missile capable of delivering conventional or unconventional warheads, the weapon system itself was revolutionary to the Air Force. The same can be said for satellites and missiles today. The Air Force has been operating satellites for almost 30 years and missiles even longer. As these systems were introduced, they revolutionized many aspects of military affairs. They can not however, be said to have had revolutionary impact on Air Force Civil Engineering. Thus, it is important to look beyond the space systems we have today to the policies that guide national efforts, to the organizations and activities concerned with space, to the technologies and systems of tomorrow and to the support concepts space dictates. These four areas have been selected as the organizing chapters for this analysis. They are broad enough to encompass the 10 subject areas mentioned above and lend themselves to assessing impact as with the simplfied GLCM example.

In assessing the impact of space on civil engineering one label, as with the GLCM example, will not suffice.

Space presents an enormously more complex analytical equation which at best may only yield approximations for each of the broad subject areas. Thus, a description for each area will be used to indicate how impact may occur and from what sector it may originate. This model will also be valuable in concluding the study's assessment and in providing a framework as well as a basis for any recommendations. Perhaps the most important aspect of modeling the analysis in this way is that it provides a tool to build relationship dependencies between the subject areas. For example, National Space Policy has an indirect relationship with NASP propulsion technology; however, the nature of their potential for change could produce a revolutionary situation for United States Space Command.

Characterizing each broad subject area by itself requires a subset of related subjects that can be analyzed in regards to their individual potential for change as well as their collective potential and interdependencies. The next section discusses the subsets of related subjects as the elements of the overall analytical outline and framework for this study.

ANALYTICAL OUTLINE

Focusing on the end research--Probable Impacts of Space on Air Force Civil Engineering--it becomes clear that many other questions relevant to the future of military space form a sort of hierarchy. The combination of the notion of a visionary bridge, the 10 selected subject areas of space related research, the 4 broad areas of analysis, and the characterizations of change which were defined above allow the creation of a conceptual framework which represents how the analytical elements of this study come together. For each element, the research provides evidence of change as evolutionary, revolutionary or radical. The framework is presented in Figure 2 and as an outline. It is ordered such that derivative questions from each element maintain sequential importance. This is not to suggest that one element is more important than another, but that one element may necessarily be related to another. For example, the importance and the utility of space necessarily precedes an understanding of Air Force space policy. Note also that any element may be a singularly controlling area of research, and as such, could logically be a critical event as in critical path analysis. An example of this might be NASP in relation to technology or, at a smaller scale, ramjet propulsion in relation to NASP. The framework follows.

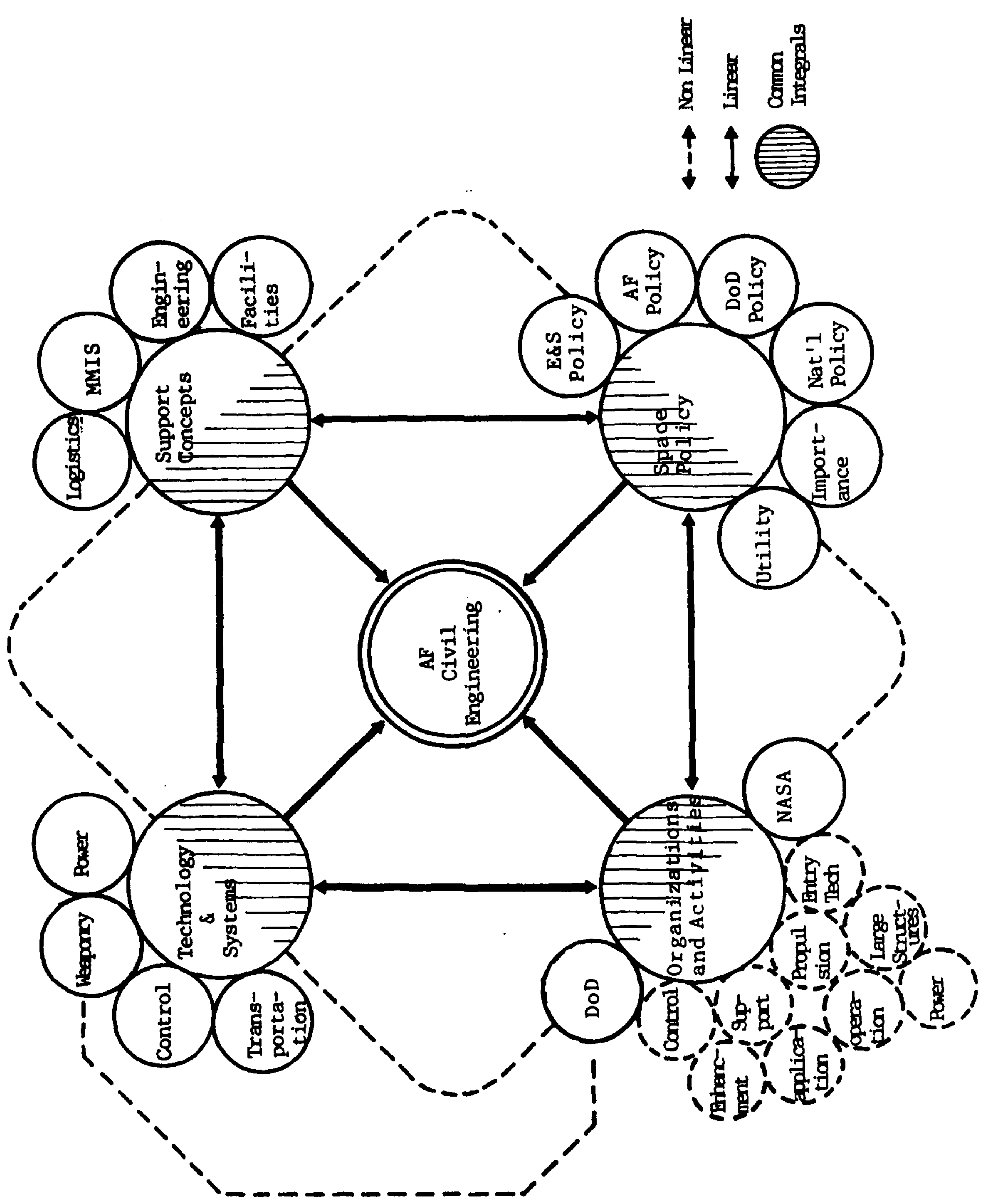

Figure 2. Analytical Framework

ANALYTICAL OUTLINE

I. POLICY

- A. Utility of Space
- B. Importance of Space
  - 1. Military Imperatives of Space
- C. National Space Policy
  - 1. DOD Space Policy
  - 2. AF Space Policy
  - 3. Engineering and Services Space Policy

II. ORGANIZATIONS AND ACTIVITIES

- A. Department of Defense
  - 1. Space Control
  - 2. Force Application
  - 3. Force Enhancement
  - 4. Space Support
- B. National Aeronautical and Space Administration
  - 1. Propulsion
  - 2. Entry Technologies
  - 3. Precision Control of Large Flexible Structures
  - 4. Power
  - 5. Space Operations

III. TECHNOLOGY AND SYSTEMS

- A. Transportation
- B. Control/Weaponry
- C. Power

IV. SUPPORT CONCEPTS

- A. Logistics
- B. Engineering
- C. Facilities

With this outline, it is possible to begin to ask the right questions that, serve as qualifiers and quantifiers for the lines in Figure 2. Those lines depict linear and nonlinear relationships. Once qualified or quantified by authoritative sources, figures, facts or trends, the individual elements can then be more plausible assessed. Again an example may help to illustrate.

In referring to Figure 2, the Department of Defense is an element to be discussed in the chapter on organizations and activities. A subelement of the DoD is USSPACECOM. As a new unified command, the USSPACECOM is undergoing rapid development and expansion. Also related to the DoD is the Strategic Defense Initiative Office (SDIO), an activity of which is currently deeply involved in kinetic energy weapons. Tracing the lines of the diagram, organizations and activities and technology and systems have not only linear relationships but common integrals in space. Additionally, the SDIO and weapons as subelements have a *nonlinear relationship as indicated.* This in fact is the case that will later be discussed. With these in mind, let us again return to the central question of *probable* impact of space operations on civil engineering by asking questions such as, "What is the forecast for fielding advanced technology in kinetic energy weapons as an element of the SDS?" Indicators which shed light on this are discussed in the chapter on technology, specifically the Brilliant Pebbles Program.[3] What this suggests is that deployment of such weapons is a hard requirement for the further development of the NASP. The implications are more support for a horizontal take-off space plane, and the bases to support such a system.[4]

As can be seen, the complexity of the relationships are initially difficult to grasp. A focused discussion based on this framework can, however, begin to explore the answers to questions that when combined can give plausible indicators of probable impacts of space on civil engineering. Literally thousands of dependencies and relationships exist. By staying with the outline, a focused analysis will uncover the ones with the most likelihood of impact. This approach will also serve to facilitate a more precise assessment from the analytical parts of the study.

NOTES

1. Letter, Chief, Plans Division, Directorate of Engineering and Services, HQ USAF, Washington, D.C. to Readiness Technical Analysis Group, Mr. Norman D. Falk, University of New Mexico, Albuquerque NM, June 1, 1988. This letter is a multiple tasking which asks for in depth future vision reports in 13 major areas, one of which is space. Extensive guidance provided as an attachment to the letter for the preparation is similar to the Air War College Defense Analytical Guidance.

2. Telephone interview with Colonel James K. Scott, HQ USAF/LEEX, 23 August 1988. In this interview, Colonel Scott indicated that a parallel effort to the RTAG tasking had his expressed approval and support. Additionally, Colonel Scott emphasized the need for the study to emphasize proactive recommendations for the civil engineering leadership to act on.

3. Theresa M. Foley, "Brilliant Pebbles Testing Proceeds at Rapid Pace," Aviation Week and Space Technology, November 14, 1988, pp 32-33. The author states that the SDI Organization has conducted flight testing of a new kinetic energy interceptor, and concludes that there can only be one realistic use of such a weapon and that is in the SDS.

4. The radical nature of light weight space based interceptors requires a continuing and, on demand, earth-to-orbit logistics system for servicing and

operation. This is a potential mission for NASP derived vehicles and could have a revolutionary impact on current U.S. antisatellite (ASAT) programs.

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CHAPTER II
POLICY

OVERVIEW

To the senior defense official, the origin of virtually every military program can be traced through an analysis of its guiding policies. It is important to see issues of policy, whether at the national, the DoD, or at a functional level, as an expression of will. In a larger sense, one cannot express will or intent without an understanding of what is realistically plausible, possible, and desired. In a special way, space in relation to matters of policy is dramatically linked. To provide an example of this special relationship, one only needs to look at the NASA Apollo program and President Kennedy's space policy of that period. Today, the SDS program represents a similar posture in regards to space for the DoD, but on a grander scale. Few could argue that such a program would have even been possible had it not been for the Reagan Administration and its very active involvement in matters of space policy.[1]

To grasp some of the foundations of current space policies, it is useful to look first at the utility of space. By this, it is meant that in today's high-technology, globally interdependent society, the use of space plays a very important role. In the area of policy formulation itself, space is quickly becoming a critical frontier in terms of national survival. From this notion of the utility of space, the importance of space from a national security strategy standpoint begins to take shape. The hierarchial policy formulation, that is, more specific functionally oriented policies, then form a linkage or connectivity that makes understanding them easier. As indicated in Chapter I, this relative hierarchial order of policy issues, all stemming from the utility of space, will be the organizational pattern for this part of the analysis.

UTILITY OF SPACE

In the early nineteenth century, if one had been asked, "what is the value of going west," the answers would have ranged from a worthless adventure, to unbounded riches and wealth. To some extent, the answers are shaped by one's psychological outlook: the former belonging to the pessimistic, and the latter to the optimistic. The same can be said about space today. For many, space is the next frontier. Brenda Forman, editor of Space World, argues that the primary utility of space is in the notion that it is indeed the final frontier and that frontiers shape the future. From a historical standpoint, her thesis is well founded.[2] Past frontiers have:

precipitated technological revolution
issued in economic change,
brought about change in political
power and order, and
given rise to new social and political situations.

From her viewpoint standpoint space becomes of immense political importance to every developed nation.

To the visionary, space exploration and use parallels the exploration and use of the North American Continent. Dr. Forman states that, "whoever explores, develops, and accurately discerns the potential of this new frontier will ultimately dominate."[3] Her view is indeed a visionary one and perhaps is not as optimistic as it is pragmatic.

Several important questions flow from this very fundamental view of the utility of space that have important ties to the hierarchy of policies dealing with space. A few that have been asked: Can we ignore this final frontier? Can we share the frontier? Do we want to share it? Should we capitalize on it and exploit it? Can we not realistically seek its domination and expect our political and social systems to survive and prosper? These questions become somewhat rhetorical to the informed citizen. More important, however, is the fact that the utility of space can be tied directly to nation-state security. In fact, the idea that nation-state long-term security can not be achieved without at least a vested effort to participate in the development, exploration, and eventual use of space is almost a certainty. Space then becomes an almost undeniable element of national security and has the potential to assume a critical role as routine access to space becomes more available.

Gemini and Apollo astronaut Eugene A. Cernan in the early seventies said, "We won't go back to the Moon or on to Mars perhaps for another generation, not until something new challenges us...."[4]

This statement better than any other one, vested with a special interest in space, reflects what almost a generation ago was a test of the new frontier without a full understanding of its utility. Author Frank White in his book, The Overview Effect: Space Exploration and Human Evolution, suggests that we no longer have a society which has ownership of a space program, but rather, we are all part of a new space movement.[5] The central idea is that the utility of space can not be reasonably denied and, in fact, it has become a fundamental element of technically developed societies. Government expenditures support his notion. Throughout the 1980s, expenditures for space programs by the Departments of Defense, Transportation, and Commerce, as well as many other government agencies, has grown remarkably. In fact, the DoD currently accounts for over 70 percent of federal expenditures in space.[6]

What this discussion begins to make apparent is that, over the last two decades, the nation's understanding and appreciation of the utility of space has been evolving. Further, evidence is provided that the nation has transitioned from owners of a space program operated by NASA, to a space oriented society dependent of continued exploration, development and eventual control of space for its well being. History supports the idea that, if space is accepted as a frontier, perhaps it is the final frontier. Continuing on with the subelements of space policy, the next link is the importance of space.

IMPORTANCE OF SPACE

Few things can be more important to a society than its survival. From a national security standpoint, there is ample evidence that the leaders of our nation have placed great importance on space for this reason; however, there are other national interests related to space that are important as well. Unique to these other interests is the idea that space provides a medium or theater of operations to provide protection for them. They are territorial integrity, economic well being, and favorable word order.[7]

Interestingly enough, all are tied in some way to the issue of security for societies. Are there any areas of importance that are completely void of the security factor? The ones that have been most fruitful include scientific experimentation, technology development, climatological study, weather forecasting, and commercial navigation. Others exist, but suffice it to say of these other areas of importance, space has provided a medium to further our understanding and knowledge of earth related matters. Perhaps the single most important aspect of space is simply that it is a new frontier for mankind.

It is important to emphasize what appears to be the obvious. The last three decades have failed to yield any truly important aspects of space that are not tied in some way to national security. Efforts to continue peaceful exploration of space by such programs as skylab and the recent development of a space station program have, in the end, yielded to overarching security requirements and resources. For example, the space shuttle program was a fairly pure civilian space activity until the lack of funding forced NASA to seek out defense missions and assistance.[8] Another example, and perhaps more convincing, is current thinking that the NASA space station program is considered to be a national resource available to the DoD in accordance with national security interests. In recent testimony to the Armed Services Committees, Former Secretary of the Air Force Carlucci enumerated 13 candidate military uses of the space station and carefully elaborated a description and utility for each use.[9] Potential uses are:

1) direct view observations,
2) latitude/longitude location,
3) maritime observations,

4) research and evaluation of space based support of tactical operations,
5) space debris management,
6) launch detection,
7) monitor atmospheric environments,
8) monitor space environments,
9) space designation,
10) space-based communications,
11) space system servicing and repair,
12) on-orbit space construction, and
13) power production research.

Another area of nonsecurity related space activity was the Reagan Administration's initial announcement to support the development of an Orient Express. Originally envisioned as a future generation hypersonic transport, the program has, through the past 5 years, transformed itself into the National Aerospace Plane (NASP) *program*, a single stage-to-orbit (SSTO) horizontal launch vehicle. The NASP program has further transitioned to what are now called NASP derived vehicles (NDV's). These will be technologically advanced vehicles derived from NASP enabling technologies suited for specific military hypersonic and SSTO space missions.[10]

THE MILITARY IMPERATIVES OF SPACE

As with the discussion on the utility of space, the proceeding discussion on the importance of space suggests that even when fairly pure civilian programs are initiated, it is simply a matter of time and resource before they yield to more pressing national security related programs. The preeminence of national survival will, for the foreseeable future, dictate the nature and essence of our national space policy. The logical extension of this analysis is that as civilian and commercial uses of space develop and become more established, so will national interests in space and therefore security interests.

In keeping with the analytical methodology outlined in Chapter I, it appears that the importance of space evolves to redefine civilian space interests almost universally in terms of national security. An understanding of the tendency for most civilian programs to either be transformed or contribute in some significant way to the nation's security interest is central to characterizing the military's future in space. In November 1984, the commander of the Air Force Space Command, General Robert T. Herres, outlined his thoughts on the military imperatives of space to the Air Force Association's National Symposium."[11] General Herres stressed that space provides the nation the medium to put virtually any weapon anywhere at anytime. He postulated that the high-tech weaponry of the global superpowers today is becoming rapidly and increasingly dependent on space and that it is logical, and probable, to assume that in the near future militarization of space is not only inevitable, but imperative. General Herres went on to state that, "To curtail the benefits that national security derives from space systems would be a truly sinister act against our country."[12]

The vision of space General Herres presented in 1984 has been taken to its next logical point by Stephan F. von Welck. In his article titled <u>Dominance in space-a new means of exercising global power?</u>, Dr. von Welck suggests that the national security strategies of the US and the USSR are evolving away from nuclear deterrence to a strategy of space control as a primary instrument of global power.[13] This recent article cites both US and USSR pronouncements, on the use of nuclear weapons, as the basis for serious moral doubts about the efficacy of nuclear deterrence in the face of rapid and revolutionary growth of national space programs. Dr. von Welck, a lawyer and space advocate, suggests that spacefaring nations will base their security as well as their global power primarily on space systems.[14] He cites the US space budget growth of almost 70% in the national security arena under the Reagan Administration as support. He also shares an interesting perspective on the NASA report Leadership and America's Future in Space.[15] Conceptually, one civil program proposed by the report is to orbit nine large observation platforms in low-earth sun-synchronous and geostationary orbits with the civil purpose of monitoring changes in the earth's surfaces. Equipped with sophisticated all weather sensors and linked to super fast computers, these platforms would be capable of considerably improving the eyes and ears of the US in space and reinforcing the nation's space control capability. If one accepts the idea that, as in past programs, the civil programs evolve by reason of the importance of space to national survival, then there is but one more future example of the dominance of the military programs in the interest of national security. In fact there is clear linkage that this type of capability is essential to a space-based defense.

Regardless of the program, be it civil or military, the controlling factors in the end which dictate to a large extent the future are the policy statements at the national level that express political will. Without the proper political basis no program can hope to gain the resources or attention to amount to much. Having established evidence that helps understand the utility, importance, and imperatives of space, the next step in the framework is to analyze the National Space Policy.

NATIONAL SPACE POLICY

Perhaps the best indication of how to characterize future US space programs is to look closely at how the national space policy has changed since President Kennedy. Sputnik prompted formulation of US Space Policy under President Eisenhower and resulted in the creation of NASA. It was President Kennedy's vision, however, of a lunar landing that really energized the scientific and engineering communities to develop the technological capabilities needed for a sustained US presence in space. President Nixon's space policies gave space a high but limited priority. Budget restrictions and competing domestic priorities forced the space program to focus on practical applications of the technologies in hand. The single most important initiatives of the Nixon-Carter space era were the Space Shuttle, Skylab, Viking and Voyager programs. Throughout the 1970s, the vision of space as a new frontier was held in check by troubled leadership plagued with other problems. In the late 1970s, President Carter's presidential directives, 37 on national space policy, and 42 on civil space policy, laid the foundations to focus the national security establishment on a broader understanding of space and its potential.[14] Both directives failed, though, to provide for any long-term space goals and lacked a visionary approach that can, today, be seen in our nation's inadequate earth-to-orbit lift capability. The Challenger tragedy and the resulting grounding of the shuttle fleet serve as concrete examples of space policy without vision.

President Reagan's space policies are excellent examples of visionary leadership that represent, clearly, political will to support space programs and, in some eyes, recognize a space movement society. They embody a full appreciation of the utility and importance of space. Table 1 shows in tabular form the salient features of the policies through the present.[17] Not only have the past 8 years provided more specific policy with clear goals, it has expanded in a revolutionary way. This enormous progress in the promulgation of national space policy provides solid evidence that the 1980s and the 1990s hold substantial revolutionary potential for national security space programs and, to a large extent, space in general. Perhaps the most important aspects of the Reagan Administration's contribution to space are the visionary leadership and enduring commitment which focused the nation on goals that leverage the high technology advantage our society has over the Soviets. In the end, however, whether by design or by default, policy has created a revolution in our country's pursuit of space that is evident throughout the national security establishment.

Table 1. Revolution in National Space Policy

STATEMENT/GOAL	80-82	83-86	87-90
Commitment to peaceful exploration	X	X	X
National security goals recognized as peaceful	X	X	X
Commitment to international cooperation	X	X	X
Commitment to pursue inherent right of self-defense	X	X	X
Develop STS further for national security needs	X	X	X
Study space arms control	X	X	X
Rejection of claims to sovereignty in space	X	X	X
Recognition of space systems as national property	X	X	X
Right to pass through and operate without interference	X	X	X
Significant space-based role for military C3I	-	X	X
Elimination of ballistic missile threat (SDI)	-	X	X
Commitment to enhance survivability and endurance of space systems	-	X	X
Development and deployment of ASAT capability	-	X	X
Close coordination for national security and civil space programs	-	X	X
Establishment of a Senior Inter-agency Group (SIG) on space	-	X	X

Table 1. (Continued)

STATEMENT/GOAL	80-82	83-86	87-90
Establishment of a permanent manned space presence	-	-	X
Development of new space transportation systems	-	-	X
Develop inexpensive heavy earth to orbit lift system	-	-	X
Expansion of ground infrastructure	-	-	X
Development, production, and operation of enduring and robust space systems	-	-	X
Establishment of USSPACECOM (DoD)	-	-	X
Establishment of the Office of Commercial Space Transportation (DoT)[18]	-	-	X
Deployment and operation of first large space station with military purposes	-	-	X
Close coordination for SDI, national security and civil space programs	-	-	X

X = Present in policy statements of the periods shown

DOD SPACE POLICY

DoD Directive 5100.1, dated 31 December 1958, provides the framework that relates national policy to DoD policy.[19] Essentially, it charges the armed forces to uphold, advance, and implement national policy. Although issued prior to current space policies, its application extends logically into the hierarchy of space policy in general and establishes a requirement for the DoD to have a specific space policy.

Present DoD space policy is a natural extension of the national policy, is fully consistent, and is fully supportive. All of the elements shown in Table 1 as part of national policy are elements of DoD space policies as well. The most significant aspect of current DoD space policy, however, is the formal recognition of the requirement to establish a Unified Command under the Joint Chiefs of Staff (JCS). For the purposes of this study, USSPACECOM has an especially important meaning. As a warfighting command, the USSPACECOM provides tangible evidence that space as a theater of operations, and not a unique medium, is a key element of US national security. This distinction was emphasized by General Lawrence A. Skantze, then Commander, Air Force Systems Command. In an address he proposed that in 1985 the defense establishment had reached a critical mass in terms of space, and that along with USSPACECOM, quantum leaps in technology and space capability were on the immediate horizon.[20] In characterizing mid-decade DoD space policy, there is support for the idea that through the early 1980s it was evolutionary and that in the 1985-86 time frame it begins to have a more revolutionary nature.

Characterizing current DoD space policy is somewhat more difficult. In September 1988, General John L. Piotrowski, Commander of USSPACECOM, commented that space operations was presently in a natural process of maturation from a research and development orientation. Additionally, he suggested that "any evolutionary process is difficult to recognize."[21] In summarizing the DoD space policy in respect to National Space Policy, it can be said to have three broad objectives, all of which are important to characterizing current DoD space policy. General Piotrowski describes them as:

1) Assured mission capability, to include
   - a proper balance of robust constellations,
   - increased survivability of space assets,
   - adequate and responsive launch facilities,
   - redundant control networks, and
   - war reserve stocks of on-orbit spare satellites.
2) Exploring the potential of military man in space and developing new technology to increase performance and lower the costs of support to the SDI.
3) Developing a general space control capability at the earliest possible date.[22]

It is accepted that these objectives are, in fact, the major objectives of DoD space policy. Clearly, the path from research and development to operational capability may be evolutionary, but the application of such capabilities can surely be considered revolutionary. The concept of space control, taken to its logical conclusion, provides reinforcing support for Dr. von Welck's theory of global power belonging to the spacefaring nations, and the associated national security implications of such a situation. The next step in the analysis is to explore the Air Force space policy, to see its relationship and implementing objectives.

AIR FORCE SPACE POLICY

On 2 December 1988, the Chief of Staff and Secretary of the Air Force wrote...

> "we have recently completed an intensive review of the role of the Air Force in space. That review concluded that space operations can have a decisive influence on future terrestrial conflict. Therefore, we must make a corporate commitment to integrate spacepower throughout the full spectrum of Air Force capabilities...."[23]

Former Air Force policy statements on space emphasized indirect combat and combat support roles for space assets. The change in tone of the current policy and the choice of words indicate that the Air Force has chartered a new and more critical role for space assets than previous policies allowed. Overall, the policies, both former and current, address space in terms of four broad categories:

1) Space Control,
2) Force Application,
3) Force Enhancement, and
4) Space Support.

Former policies stated "...space systems have the potential to perform...."[24] As opposed to the statement above, a belief that systems have potential versus a belief that "...operations can have a decisive influence..." seems to indicate a dramatic shift in thought concerning the value of space operations to national security. The report of the Air Force Blue Ribbon Panel on Space suggests, "spacepower will play as decisive a role in future combat as airpower has today."[25] This rather dramatic redirection of space policy obviously is meant to recognize the role the Air Force Space Command will play in USSPACECOM. Further elaboration of the policy, in respect to the overall integration of space into the Air Force, suggests near-term deployment of space-based weapons. A subtenet of the policy states that...

> "we must be prepared for the evolution of spacepower from combat support to the full spectrum of military capabilities."[26]

Just exactly what was meant by full spectrum of military capabilities was clarified in the sections of the policy dealing with space control and force application. The section on control states that...

> "the Air Force will acquire and operate antisatellite capabilities. The Air Force will provide battle management/C^3 for US space control operations, and will perform the integration of ASAT and surveillance capabilities developed for space control operations..."[27]

This aspect of the policy supports the notion Dr. von Welck put forth regarding global power being a function of the spacefaring nations' dominance in the control of space. How the control of space links up with global power can be seen in the section of the policy on force application, it states that...

> "...the Air Force will acquire and operate space-based ballistic missile defense assets, will provide battle management/C^3 for BMD and will integrate

> BMD forces. The Air Force will acquire and operate space-based weapons..."[28]

It is important to note that these features of the policy are predicated on a BMD deployment decision and technical feasibility of such systems. At the same time, however, the simple recognition of this aspect of force application opens the door to a new future. President Kennedy's vision suggested that such political denial could never be in the interests of the nation with his statement that...

> "if the Soviets control space, they control the earth, as in the past centuries the nations that controlled the seas dominated the continents."[29]

The force enhancement and space support categories of the new policy represent the logical extension of past policies to current requirements and capabilities. In the force enhancement area, the most significant addition to the policy is the commitment to a space-based wide area tracking and targeting capability. Complimenting this program will also be a space-based space surveillance capability. These programs are requisites to the force application objectives and thus natural extensions.

The most significant aspect of the policy is in the space support area, dealing with launch and control capabilities. Assuring a robust capability, as the policy calls for, dictates broad and sweeping new programs and has led to an implementation strategy that requires a broader expendable launch vehicle base, an advanced launch system, and expanded launch facilities. The projections for launch requirements led to the need to look at both evolutionary and revolutionary approaches to space access. Both types of approaches have been envisioned as necessary to carry out the full intent of the policy. What would result then is a launch capability which is in effect a system of systems.[30]

Clearly, the more specific Air Force space policy can be described as fully consistent with DoD and national policy. In addition, the space control, force application, and space support categories of the policy represent significant changes in past policies. The whole notion of integrating space across the full spectrum of Air Force activities is, in and of itself, not an evolutionary idea. Taken as a whole, the policy is revolutionary. Even where the elements of the policy are encumbered by future decisions, such as the BMD decision or NASP technical limits, there are few realistic alternatives except to press on. What this study suggests is a revolutionary Air Force space policy. The next step of the analysis is to look at the Engineering and Services space policy.

ENGINEERING AND SERVICES SPACE SUPPORT POLICY

The policy concerning space and space support governing civil engineering is a relatively new policy. It has five major tenets, four of which relate directly to civil engineering.[31] As a functional support policy, it is *consistent* with Air Force space policy and visionary in nature. The first tenet calls for achieving early involvement in space concept development and systems planning. Taken to its logical conclusion, this tenet provides for civil engineers to be actively involved in all aspects of space, including space facility hardening criteria development, space station design and habitability and environmental space concerns. The second tenet is to provide support to the ground components of military space capabilities. Again, in extrapolating out what kinds of activities this might include, one could envision battle damage repair of satellite control stations, pre-orbit test assembly of space facilities and even rapid runway repair for NASP derived vehicles. The third tenet calls for the provision of the required standards of facility reliability and performance. Activities associated with this tenet could be the development of complex uninterruptable power grids, and none-to-low maintenance construction methods and materials for critical control facilities. The fourth tenet calls for the development of capabilities to construct, operate, maintain, and repair facilities in space. Such capabilities may include structural design for zero gravity applications, enhanced radiation and thermal insulating construction techniques and many others which have been pioneered by the aerospace industry and NASA.

In reviewing this policy, it can be characterized as fairly revolutionary when taken in context with current mission requirements. Perhaps, the most important aspect of this policy is the premise that orbiting platforms may be more like facilities than vehicles or spacecraft and that the civil engineering community will have important duties in the provision, operation, and sustenance of such facilities. Current writings on space logistics support this notion. In fact, many recent articles suggest that the first generation of space stations will, in fact, be logistics nodes or depots from which on-orbit maintenance of space assets and space construction will be based.[32] Should this be the case, the question that becomes central to this section, and the study, in general, is when can we expect this to be feasible? Before we turn to the subjects of organizations, activities, and technologies, a brief recollection of this chapter's findings would be beneficial.

ANALYTICAL SUMMARY

- Space policy and programs in the 1960s can be characterized as revolutionary.
- Space policy and programs in the 1970s can be characterized as evolutionary.
- The utility of space demands a corresponding national security importance.
- World domination can logically be a function of space control.
- The utility of space is becoming a fundamental element to technically advanced societies.
- The preeminence of space in national security concerns preempts civilian space programs.
- The military imperatives of space will dictate future national space policy.
- Current national space policy is revolutionary in character and contains broad and sweeping objectives.
- Current national space policy is leveraged to use US technological advantages as the basis for future national security.
- DoD Space Policy is fully consistent and equally as visionary as national policy and, as such, is revolutionary.
- Air Force space policy is consistent and equally as visionary as DoD policy, and includes objectives in space control, force application, and space support.
- Engineering and Services space policy is visionary and revolutionary.

NOTES

1. Air University, Air Command and Staff College, Space Handbook AU-18, January 1985, University Press, Maxwell AFB, Alabama, pp. 15-5, 15-8.
2. Brenda Forman, Why Space Is Important, Space World, Vol Y-2-290, p. 13.
3. Ibid.
4. Frank White, Broadening the Perspective, Space World, Vol. Y-2-290, p. 14.
5. Ibid.
6. Air War College, Air University, Maxwell AFB, Alabama, USAF Blue Ribbon Panel on Space, Final Report, November 1988.
7. SPACE HANDBOOK AU-18 pp. 15-5.
8. White, "Broadening the Perspective," p. 16.
9. "Potential Department of Defense Use of the Permanently Manned Space Station," SPACE POLICY, August 1988, pp. 265-268.
10. "Briefing, Notes National Aerospace Plane (NASP) Program Charter" NASP Systems Program Office, Aeronautical Systems Division, Wright-Patterson AFB, OH, November 1988 (Typewritten).
11. Edgar Ulsamer, "The Military Imperatives In Space" Air Force Magazine January 1985, p. 92.
12. Ibid.
13. Stephan F. von Welck, "Dominance in space-a new means of exercising global power?" SPACE POLICY, Vol 4, No 4, November 1988, p. 319.
14. Ibid, p. 323.
15. Ibid, p. 324.
16. Space Handbook, Au-18, pp. 15-7.
17. This table was prepared from the three references. National Security Decision Directives (NSDD) are normally classified.

The sources below all presented unclassified discussions on the material. Space Handbook Au-18 pp. 15-78; Air University, Air War College, Space Command Chair, Space Issues Symposium, April 1988, Maxwell AFB, AL, Pg. 80-83; Presidential Directive on National Space Policy, The White House, Office of the Press Secretary, Washington DC, 11 February 1988.

18. The Office of Commercial Space Transportation (OCST) within the Department of Transportation was created by Executive Order and by the Commercial Space Launch Act of October 1984. It was not until 1987 however that the office became fully operational. see, "Commercializing Space: A conversation with Courtney Stadd," SPACE WORLD, May 1988 pp. 23-26.

19. Space Handbook Au-18, pp. 15-9.

20. Lawrence A. Skantz, General, "Military Space, A New Era For Force Structure Decisions," Vital Speeches of The Day, 15 November 1985, pp. 205.

21. John L. Piotrowski, General, "Space Evolution," Signal, Vol 43, September 1988, p. 27.

22. General Piotrowski expands on these objectives with specifics which are fully compatible with Air Force Space Policy at the time. On 2 December 1988 the Department of the Air Force issue an Information Memorandum on Air Force Space Policy which more completely illustrates how the DoD and specifically the Air Force will approach these objectives. Ibid.

23. Letter, Secretary of the Air Force, Chief of Staff USAF to all major commands and separate operating agencies, Subject: Air Force Space Policy, 2 December 1988.

24. Space Handbook pp. 15-12.

25. "USAF Blue Ribbon Panel Report."

26. Letter Air Force Space Policy, 2 December 1988.

27. Ibid Attach 1.

28. Ibid Attach 2.

29. Piotrowski, "Space Evolution," p. 28.

30. Briefing notes, Air Force Secretariat (SAF/AQS) Colonel Carol A. Yarnall to the Engineering and Services Space Liaison Group (ESSLG) 31 August 1988.

31. Letter, from Director of Engineering and Services HQ USAF subject Engineering and Services Space Support Policy, to all Major Commands/DE, 2 December 1987.

32. The articles referenced will be specifically discussed in the chapter on technology. A good synopsis of the topic in general can be found in the recent White Paper on Space Logistics. Letter with attachment from the assistant DCS Plans and Programs, HQ Air Force Logistics Command Wright-Patterson AFB, OH, Subject, "White Paper on AFLC Space Logistics, Strategic Issues and Options," to call major logistics activities, 7 December 1988.

CHAPTER III

ORGANIZATIONS AND ACTIVITIES

DEPARTMENT OF DEFENSE (DOD)

The DoD has undergone significant change since the Reagan Administration's first space policy in 1982. A recap of the major events will set the stage for this chapter of the study and serve as an excellent point of departure for analyzing how past events and current programs may help characterize the future. Major DoD organizational changes follow:

> September 1982, Air Force Space Command was activated,
>
> October 1983, Naval Space Command was activated and the Strategic Defense Initiative Office was created,
>
> September 1985, US Space Command was formed,
>
> August 1986, Army Space Agency was activated and, in April 1988, it was Redesignated Army Space Command.

These changes, as suggested in Chapter II are largely a result of DoD decisions on how the department would organize itself to carry out the broad and sweeping policy objectives of the 1980s. Quite obviously, the creation of USSPACECOM was in fact the vision of the Joint Chiefs of Staff as the single unified command, with space as its theater of operations. More then just a vision, by 1985 it had become clear that the military dependence on space had, become irreversable, and a single advocate for space operations was needed by the National Command Authorities.[1] What had actually happened was a converging set of influences attained what General Skantze called a "critical mass."[2] There was a lot more than just organizational changes happening. These new commands were not the "same monkies on different trees." These were to be responsive to large-dollar weapons system questions, and whole new sets of force structure decisions. Most of all, the advocacy for the space debate needed a central focus in order to accomplish these tasks. Much more can be said in respect to defense establishment organizational changes; however, suffice it to say, these changes and their associated rationale were quite revolutionary in the context of DoD organizational structure.

In terms of organizational activities, it is more useful to analyze the activities in relation to governing policy. Therefore, the study will proceed along the lines of the four broad categories of DoD and Air Force space policy. The first is space control. The ASAT debate is at the heart of the earth-based space control activity. General Piotrowski has suggested that the US is in a dangerous position in respect to our inability to control space and that public awareness of the defense requirements may in fact be a significant controlling factor in the type of support and the amount of resources that can be expected for the program.[3] April 1988 brought about the needed realization that an anti-satellite capability was essential to national security and that all three services, with USSPACECOM as their focal point, were heavily involved in determining the best solutions for the near-, short-, and long-term requirements. Options range from the F-15 ASAT program to ground-based kinetic-energy weapons and directed energy lasers. Space-based ASAT capabilities also form part of the space control category, and recent developments in the Brilliant Pebbles program indicate that the concept of space-based interceptors is fast becoming an important consideration.[4]

The second category of activity is force application. Colonel Yarnall's presentation to the ESSLG likened force application to the Strategic Defensive Initiative; however, it is more than just SDI.[5] Another significant aspect of activity in this category is that force applications is now considered to include the traditional space combat support operations and the notion of space combat. Obviously, a discussion of the fast-paced SDI program activity would be far beyond the scope of this study. It is possible, however, to cover some of the major program indicators to characterize its relative impact. The Air Force is responsible for over one-third of the total SDI budget, and it is expected that this proportional responsibility will remain into the foreseeable future.[6] The Defense Acquisition Board approved, in 1987, six technologies of the SDI, Phase I, missile defense system for demonstration and validation.[7] The program has been the focus of federal budget reduction efforts and has recently become more integrated and distributed among the services.[8] The program has the political support of President Bush, but will most likely continue to be a candidate for funding reduction.[9] Regardless of the slowdown in funding and the continued debate on the appropriateness of the SDI program, there is widespread agreement that it has had a revolutionary effect on the DoD and will continue to do so.

In the area of combat support as a force applications activity, the notion of a military space station holds potential for enormous change. Open literature suggests that this activity is possible and former Secretary of Defense Carlucci has testified before congressional committees on how such a station might be used by the DoD.[10] These uses were outlined in Chapter II. For purposes of this section, it can be said that great potential for change could exist if a military space station was to be developed. There is little open evidence to suggest that this is the case. Additionally, there is no evidence to suggest what defense organizations would be involved in such an activity. One might speculate, however, that a military space station would be primarily an Air Force activity.

The third broad activity is force enhancement. This category is very active and, based on DoD and Air Force policy, destined to become even more so. The basic satellite functions, all of which have active programs, are surveillance, early warning and assessment communications, navigation, meterorology, oceanography, and geodesy. Located in conjunction with facilities around the world, the constellations these satellite systems form, and their respective earth based facilities, represent current missions at 24 CONUS and 25 overseas installations and a manpower force of over 23,000 people.[11] As with the SDI discussion, anything more than a simple overview of this area is beyond the intent of this study. In characterizing the activities associated with the notion of force enhancement, it is easy to see that the Air Force's and the DoD's activities are rapidly evolving with every technological breakthrough in electronics, composite materials, optics, and data processing. Long range projections for satellite control call for an architectural concept that should significantly change and enhance satellite survivability, capacity, and efficiency. Projections indicate that by the year 2015, over 150 satellites will be on-orbit compared with a present total of 55.[12] In the area of emerging technologies, the concepts of space-based radar and complementary infrared detection technology could significantly alter the mission composition of existing constellations.[13] Beyond this, the entire arguement for growing interoperability of systems and artificial intelligence capability of future computers could foster yet another generation of complex satellite constellations.[14] Suffice it to say, there exists today enormous potential for revolutionary, if not radical change, in the broad area of force enhancement.

The fourth broad area of organizational activity is space support. Colonel Yarnall suggested that this area is, to a large extent, analogous to launch and transportation capabilities.[15] To avoid duplication with the section of study on transportation technologies, and in the interest of briefity, this section will again cover only the major programs. In the area of expendable launch vehicles (ELV) a robust program has been requested to expand the current launch fleet and meet today's requirements for unattended cargo.[16] Accompanying this expansion is an associated requirement for improved launch facilities. There are numerous studies that outline the need for an assured access to space via a force mix of unmanned and manned vehicles.[17] A few of the proposals suggest an unmanned Space Shuttle II for heavy lift, and Delta, Atlas, and Titan ballistic missile derivatives for medium lift. Officially the DoD has joined forces with NASA to pursue what is commonly called an Advanced Launch System (ALS) which is designed to provide the assured access to space, dictated by national security.

The most important point in the current launch equation and valid for the short term is that "national security objectives cannot be met through simple evolution of today's space transportation system and expendable launch vehicles."[18] Future projections envisioned to provide the capability include adaption of technological enhancements to current boosters, and allowing them to function as transition vehicles until the ALS is operational. Further on the horizon is the NASP derived family of vehicles which will provide revolutionary capability.[19]

Accompanying assured launch are advanced concepts of space logistics such as on-orbit maintenance for satellites. Present concepts include orbiting transfer and maneuvering vehicles to assist in space-based maintenance programs, as well as orbiting maintenance platforms and logistics nodes. Parallel to on-orbit maintenance programs are conceptual studies for on-orbit consumable storage and space resupply.[20] Most of these programs and concepts are only ideas today; however, the apparent support and momentum many of them carry could serve as catalysts transferring them quickly into operational systems as technical and resource problems are overcome. Again, the evidence supporting such programs tends to characterize them as somewhat revolutionary programs, although their dictating requirements are natural extensions of many current programs. Overall, the activity in the area of space support can easily be considered revolutionary, mostly due to the enormously broad nature of space support and the relatively deficient nature of current capabilities. Revolutionary programs are essential to bridge quickly into future operational capabilities.

Putting the above analysis in perspective, it can be seen that DoD organizations and activities have undergone enormous change in the 1980s. Additionally, the activities in which these organizations are engaged tend to be more revolutionary in character than evolutionary. Further, the future projections for many of the organizational activities are rooted firmly in policy guidelines stemming from national space policy and, as such, have a good chance to eventually come to fruition. The next section of this chapter will cover the National Aeronautical and Space Administration (NASA).

NATIONAL AERONAUTICAL AND SPACE ADMINISTRATION

NASA's charter in space has expanded significantly over the past decade. Currently, NASA has five major divisions for space and space related programs. They are 1) Space Science and Applications, 2)Aeronautics and Space Technology, 3)Space Flight, 4)Space Station, and 5)Space Operations. The NASA's long-range plans offer an overview of each of these divisions from which logical projections of future capabilities have been made. Taking into account the National Space Policy, that has as a central feature the cooperation of civil, military and commercial space entities, it is reasonable to assume that the same capabilities developed for civil programs will have military utility, if they are not in fact jointly developed programs. Regardless of initial intent, recent history supports the national security utility of space and, as discussed in Chapter II, the military imperatives then follow. A close look at key NASA space programs offer insight into the future of DoD in space and in turn some insight for civil engineering. The broadest area of NASA activity for the purpose of this study is in space technology. This will be the first topic of discussion.

NASA recognizes five areas of space technology which it considers enabling technologies for many of its other programs. These five areas of space technology are also recognized as key areas by the DoD and include, propulsion, entry technologies, precision control of large flexible structures, power and space operations.[21] In many research and development circles these are known as technology pulls. NASA refers to them as driver missions. Figure 3 shows the projected applications of the driver missions focused on three major areas throughout the next 20 years.

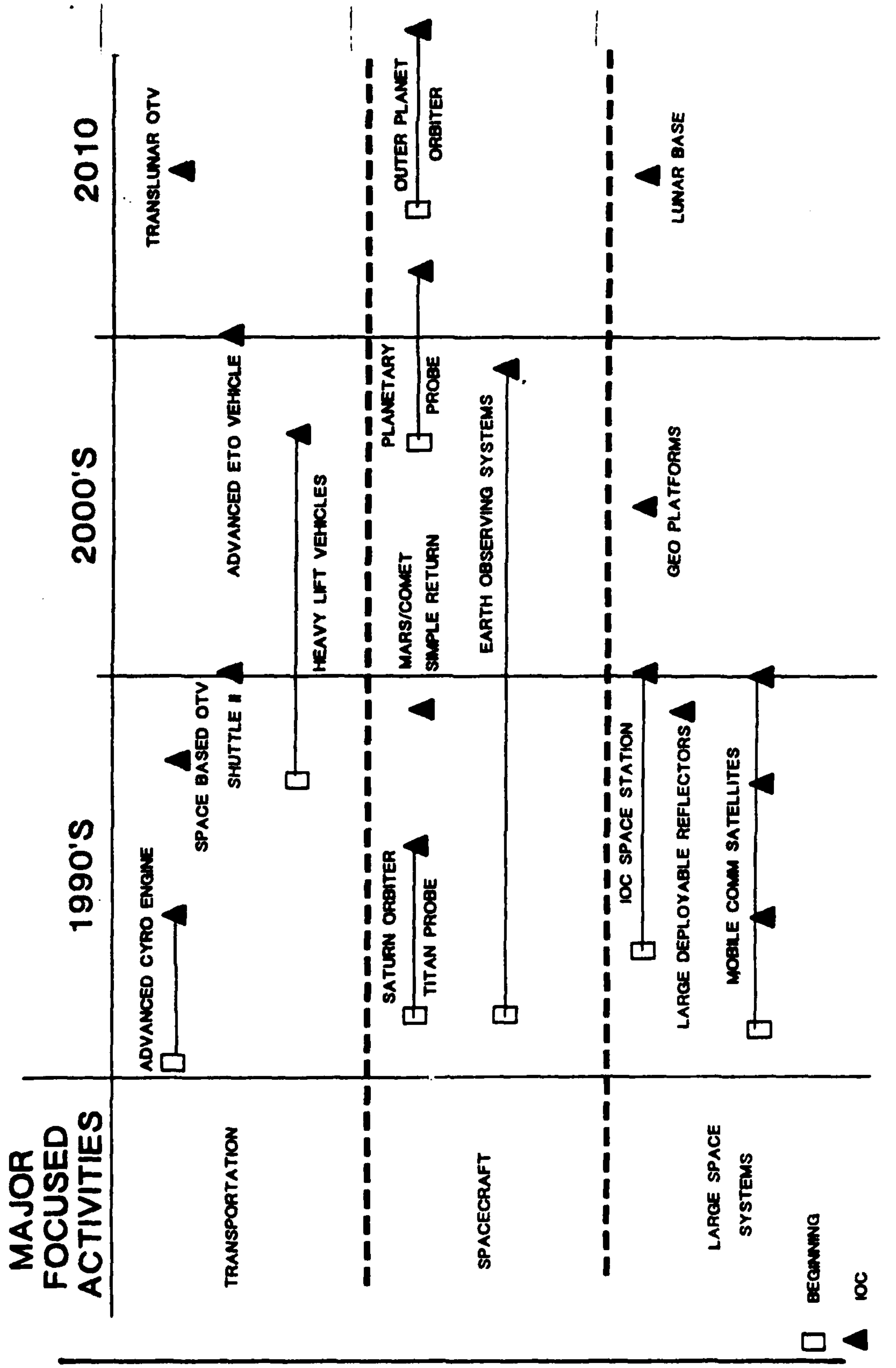

Figure 3. Projected Applications of Driver Mission Technologies.[22]

In the area of transportation, driver mission technologies are expected to develop a NASA space-based orbital transfer vehicle, an advanced earth to orbit vehicle, translunar OTVs and, perhaps most important, a new generation of heavy lift vehicles. In the area of spacecraft, the earth observation systems culminating in continuous geosynchronus coverage are the key programs. Perhaps most closely connected to civil engineering are the space station, large deployable reflectors, geosynchronus platforms and eventually the lunar base.

NASA has outlined more specific capabilities along 20-year time lines that allow a better appreciation of what they anticipate each of the five driver mission technologies to yield. Table 2 depicts the specific outcomes of propulsion with high potential value for DoD space systems. While the DoD has not, in open sources, related corresponding defense missions for these capabilities, their general usefulness is apparent. Table 3 depicts the more complex nature of how Entry Environments facilitate various systems, and lead to more efficient and mature applications. The sub-technologies have significance for defense systems in that they are the areas that must be mastered to allow production and deployment decisions. Table 4 shows the timeline for assembly and control of large complex structures. By 2010 the capability to routinely assemble large complex active structures will exist. This has enormous implications for civil engineering with obvious defense application of such technologies.

Table 5 shows the evolution of space-based high capacity utility-type systems. It is interesting to note that the evolution of power systems can be projected in decades by orders of magnitude in actual capability. Current SDI research may accelerate these timelines and bring nuclear generation capabilities into the realm of capability much earlier than the NASA projections. The last mission driver technology area is space operations. The major applications of space operations technologies are routine manned and adaptive unmanned operations. Table 6 shows the capabilities that this technology is expected to make possible. As with the complex structures and power technologies, space operations has important long-term implications for civil engineering. A simple comparative analysis with present day terrestrial functions reveals utilities in virtually every area.

Table 2.

Projected Outcomes of Propulsion Technology for Routine Space Transportation.[23]

Routine Space Transportation

1990 - 2000	Long-life earth-to-orbit systems
	Space basing
2000 - 2010	Airbreathing earth-to-orbit engines and fuels
	Fail-safe rocket systems
	High-performance/moderate-thrust nonchemical systems
	Lunar OTVs
2010 - 2020	Lunar derived propellants (O_2, H_2 extraction)
	High-performance/high-thrust propulsion systems
	Routine earth-to-moon transportation
	Breakthrough systems, metallic H_2 and metastable He

Table 3.

Projected Outcomes of Entry Environment Technologies.[24]

1990 - 2000

Aero Assisted OTVs

Rarefied flow modeling
Reversable high-thermal load temperatures
Adaptive guidance

Transatmospheric Experiments

2000 - 2010

Planetary Aerobraking

Nonequilibrium flow modeling

Transatmospheric Vehicle

Actively cooled hot structures
Light weight materials
Adaptive control
3-D viscous flow modeling

2010 - 2020

Transatmospheric Transport

Internal cyrogenic tankage
Long life metallic temperatures

Outer Planet Orbiters

Magnetohydrodynamic flow control

Table 4.

Projected Outcomes of Large Flexible Structures Technologies.[25]

Assembly and Control of Large Complex Structures

1990 - 2000

Deployable systems

Distributed control

Modular habitat assembly

2000 - 2010

Routine assembly of large passive structures

Precision control

Limited space based fabrication

Large habitat assembly

2010 - 2020

Routine assembly of complex active structures

Space habitat construction

Extraterrestrial materials extraction/processing

Large habitat construction

Table 5.

Projected Outcomes of Power Generation Technologies.[24]

Power Capabilities

1990 - 2000 (Hundred Kilowatt)

Dynamic systems (solar)

High efficiency photovoltaic systems

Long life regenerative energy storage

Automated power management

Thermal bus

2000 - 2010 (Megawatt)

Large photovoltaic arrays

Dynamic systems (nuclear)

High voltage systems

High energy, regenerative energy storage

Autonomous power management

Liquid droplet radiator

2010 - 2020 (Multi-Megawatt)

Mixed sources (solar, nuclear, chemical)

Utility services

Totally space/lunar based

Power depot/power beaming

Table 6.

Projected Outcomes of Space Operations Technologies.[27]

Space Operations

1990 - 2000

Automated fault diagnosis and mission planning

Dexterous teleoperation

2001 - 2010

Autonomous task planning and execution

Autonomous rendezvous and docking

Cooperative telerobots

Closed life support systems

2011 - 2020

Autonomous space operations to include material processing, internal fault management, space system diagnosis and repair, environmental adatation

Lunar operations

Autonomous Mars rover

The next major division of NASA's activities which are important to this study is that of the space station. NASA expects to be operating routinely in the space station by 1996. The configuration of the base has been established to allow growth elements and unmanned platforms. Figure 4 is a diagram of the architecture. As with the enabling technologies the DoD has not, in open sources, communicated specific military missions for such a station. It is concievable, however, that the entire station, or a duplicate of it, be configured to perform the functions elaborated in Chapter II. Again the implications of such capabilities when tied to firm military requirements presents enormous challenges to the DoD, especially when one considers that the US is less than 6 years away from permanent space station operations.

On the contrary the lack of established requirements and specific funded military missions at this point in NASA's efforts supports the notion that the requirements for such capabilities are not firmly established in the DoD.

Functionally, NASA considers the station a multipurpose facility. The immediate and near-term uses include a national laboratory in space, a permanent observatory, a servicing facility, a transportation node, an assembly facility, a manufacturing facility, a storage depot and a staging base.[29] Conceptually, NASA envisions the station to be an evolutionary development process beyond its initial operating capability. As more and more of the enabling technologies, developmental engineering and program definitions are mastered, the station program will become the baseline for virtually every aspect of space operations. From this standpoint the program has enormous implications for defense space systems and deserves very close attention.

The last major division of NASA's programs with specific relevance for this study is Space Flight. Within this division, three of NASA's long-range planning thrusts represent key activities which we are concerned with. They are orbital services, space infrastructure, and second generation space transportation systems. The major activities through the next 20 years in the area of orbital services are shown in Figure 5. As indicated on the diagram, the shift from expendable satellites to the full use of orbital services for the retrieval repair, resupply and reconfiguration of orbital systems is not far away. The Air Force presently defines such activities as space logistics and is fully engaging with NASA through the Johnson Space Center in developing these activities.[31]

Space infrastructure is the second area of importance to the DoD and involves understanding how orbital interfaces might be arranged and how the various orbital assembles come together in creating the general space environment. Two key vehicle fleets that will facilitate the infrastructure are the orbital maneuver vehicles and the orbital transfer vehicles. To draw an analogy of the importance of these vehicles, one only needs to think of them as the jeeps and trucks. These vehicles, coupled with the manned and unmanned platforms, stations and launch vehicles and arranged in low earth and/or geosynchronus orbit, form the space infrastructure. Obviously this aspect of space operations and flight is farther downstream in terms of DoD interests, but clearly none-the-less important.

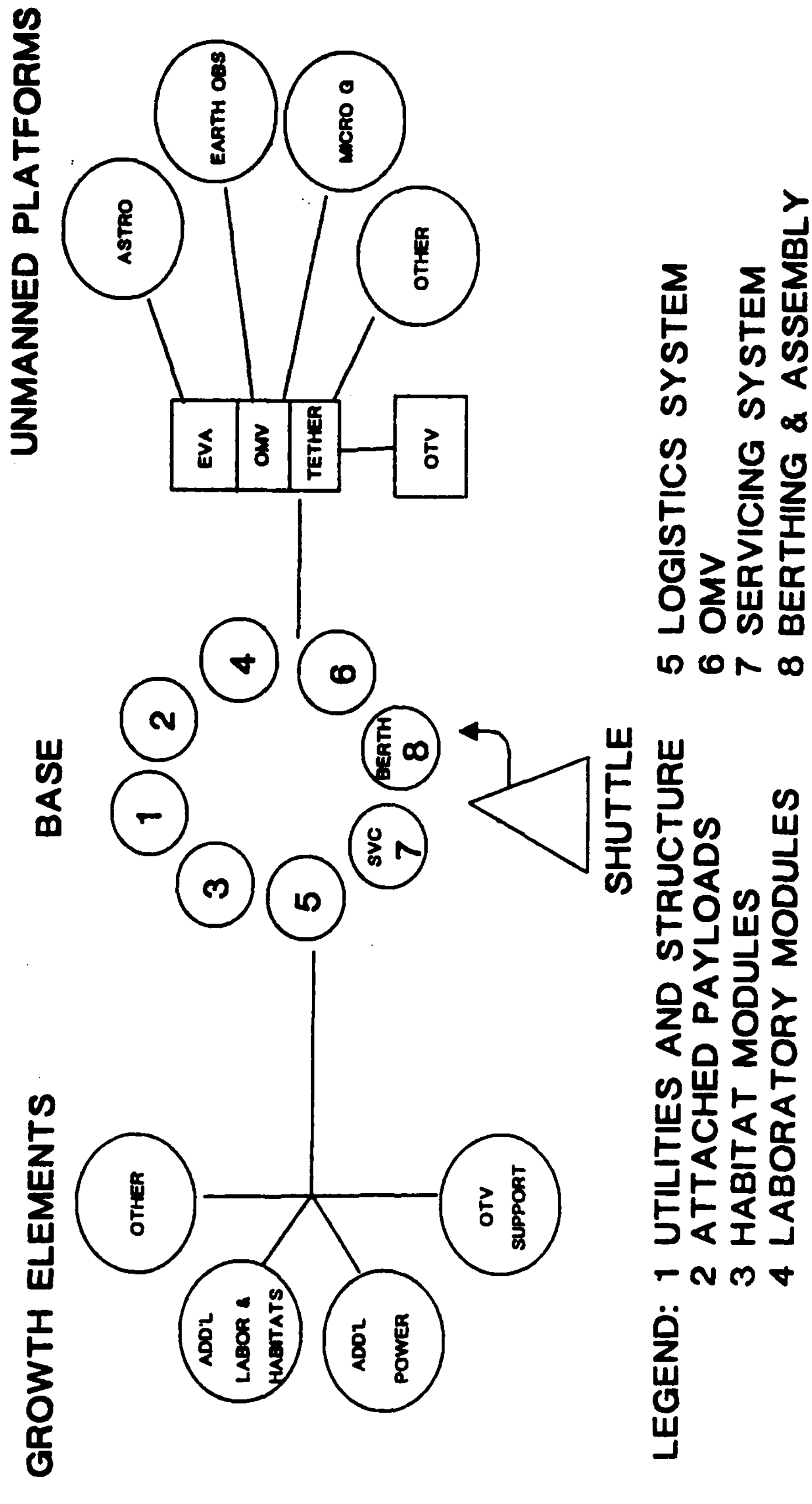

Figure 4. Space Station Architecture[28]

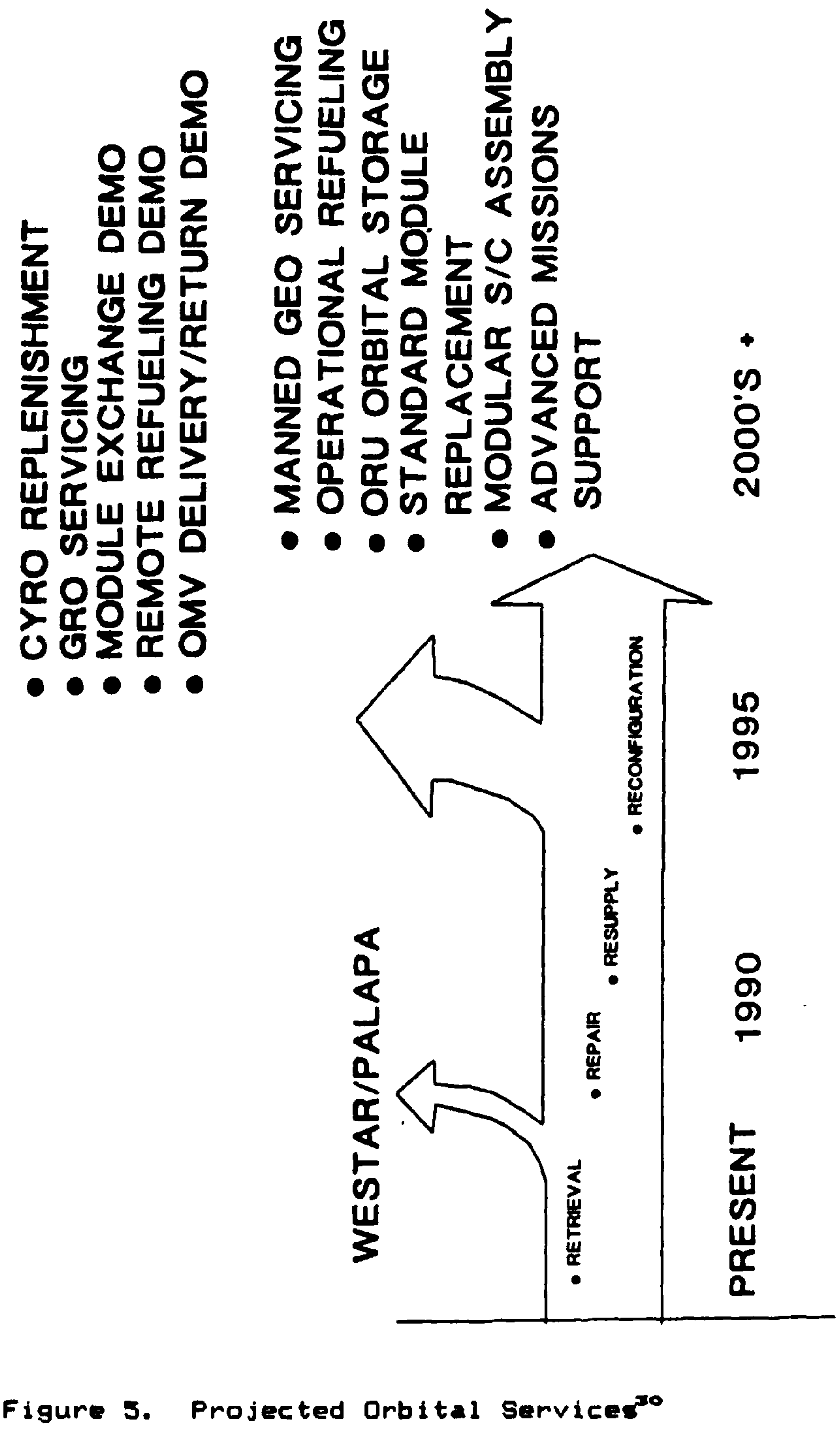

Figure 5. Projected Orbital Services[30]

The last area of NASA's Space Flight activities is the development of second generation space transportation systems. This area represents one in which the Air Force has been totally and actively involved.[32] Mentioned previously, the ALS and eventually the NASP and NASP-derived vehicles will come to make up the system, and perhaps even be a subsystem of a larger more comprehensive system. Regardless, this topic is of critical importance to this study and will be addressed in the next chapter as one of the fundamental determinants of our future in space.

ANALYTICAL SUMMARY

- The activities of the DoD and NASA are consistent with National Space Policy.
- DoD organizational changes in respect to space during the last 6 years, can be characterized as evolutionary.
- The DoD changes, especially the creation of USSPACECOM are a result of the Defense Department's Irreversible dependence on space.
- New space commands in DoD are responsive to the need to resolve weapon system and force structure decisions.
- An ASAT capability has been recognized as vital to national security.
- Ballistic missile defense systems are vital to national security.
- SDI activity is pacing US space programs in the area of force applications and is receiving continued strong NCA support.
- The use of a space station for defense missions would provide revolutionary force applications and enhancement capabilities.
- Activity in the area of force enhancement missions is progressing in a fast paced evolutionary manner.
- Future technologies offer revolutionary force enhancing capabilities such as space-based radar.
- Space support activities are progressing in evolutionary ways.
- Future technologies associated with space transportation systems possess revolutionary potential and promise assured access.

-Space logistics concepts for on-orbit maintenance of space assets are under development, are needed for future operational capabilities, and are evolving jointly within DoD and NASA.

-NASA's space divisions have active programs, strong support, and are important to the DoD.

-NASA is developing important space-system enabling technologies which are driver missions for both NASA and the DoD.

-The technologies of propulsion, entry, precision control of large flexible structures, power, and space operations are linked to NASA activities in transportation, spacecraft, and large space systems which have revolutionary potential for DoD.

-NASA's long-range plans offer a keen insight into future DoD space capabilities.

-The period 1990 to 2020 can be identified as having specific space capabilities as the result of evolutionary developments in propulsion systems, entry, and re-entry technologies, precision control of large complex structures, power generation, and space operations.

-The NASA space station has revolutionary functional utility as a national asset for the DoD.

-NASA's evolutionary activities in the area of space flight project important logistical capabilities for the DoD in space.

-NASA's evolutionary development of space infrastructure project important defense requirements.

-NASA's activities in the development of single stage-to-orbit horizontal take-off vehicles in conjunction with the DoD offers revolutionary potential.

NOTES

1. Piotrowski, "Space Evolution," p. 28.
2. Skantze, "Military Space....," p. 205.
3. Piotrowski, "Space Evolution," p. 28.
4. Foley, "Brilliant Pebbles Testing Proceeds at Rapid Pace" , p. 33.
5. Yarnell, "Briefing Notes to ESSLG," p. 26.
6. Ibid, p. 29.
7. "Space Issues Symposium" p. 392.
8. At the time of this study the FY89 Defense Budget reflected a 2% real growth. Popular media continually report the SDI program as a possible early candidate for budget reduction action. The DoD SDI budget request for FY90 is $5.6 billion.
9. Interview, Lt Col Richard Bowman, HQ USAF/LEYM; Space Policy Section, 25 October 1988.
10. "Potential DoD Use of the Permanently Manned Space Station," p. 265.
11. Yarnell, "Briefing Notes to ESSLG," p. 10-13.
12. General accounting Office, U.S.G. "Military Space Operations: Shuttle and Satellite Computer Systems Do Not Meet Performance Objectives," IMTEC 88-7, August 1988, p. 3.
13. Ulsamer, "The Military Imperatives In Space," pp. 94,95.
14. Ibid, p. 30.
15. Yarnell, "Briefing Notes to ESSLG," p. 30.
16. Ibid, p. 30.
17. General research revealed five studies by students at Air University, Maxwell AFB, addressing the questions of a force mix for assured access to space. The most current study referenced here is very similar in its

findings to a reportissued by the Office of Technology Assessment on the same subject. James B. Boyle, Major USAF "A Force Mix For Assured Access To Space," Student report, Air Command and Staff College, Maxwell AFB, AL, April 1986, pp. 1-29.

18. Yarnell, "Briefing Notes to ESSLG," pp. 32-34.
19. "Briefing Notes NASP Program Charter," November 1988
20. Johnson Space Center, "Satellite Services System Working Group Meeting #18 Minutes," NASA, JSC Houston Texas, 27,28 October 1988, pp. I-1 to I-13.
21. U.S. Congress, House, Committee on Science and Technology, <u>NASA's long-range plans, hearing's before the subcommittee on Space Science and Applications.</u> 99th Congress 1st Session, September 17-19, 1985; Washington DC, U.S. Government Printing Office, 1986, p. 54.
22. Ibid, p. 58.
23. Ibid, p. 62.
24. Ibid, p. 64.
25. Ibid, p. 67.
26. Ibid, p. 70.
27. Ibid, p. 73.
28. Ibid, p. 26, (Figure 3).
29. Ibid, p. 26, (Figure 4).
30. Ibid, p. 42.
31. Johnson Space Center, <u>SSSWG Meeting #18 Minutes</u>, pp. I-13.
32. Briefing Notes, NASP Program Charter, Title page.

CHAPTER IV
TECHNOLOGY AND SYSTEMS

TRANSPORTATION

The preceding chapters have suggested that technology and the space systems which advanced technologies make possible will be significant determinants of the DoD's future in space. This chapter looks at the three technological areas which have the greatest potential to shape the future for DoD, the Air Force and, in turn, Engineering and Services.[1]

Transportation, as a pacing technology driver, is shaped largely by the NASP program for revolutionary impact and the ALS for evolutionary impact. In a sense, the evolution of ELVs and the space shuttle can almost be assumed due to national recognition of space access imperatives and by current technological capabilities. Therefore, the NASP program becomes the focus of this section since, it alone, offers the only real opportunity to make access to space far less expensive and immediate, thus revolutionizing space access.[2] In conjunction with far lower costs to orbit, the NASP SPO at Wright-Patterson AFB is quick to stress 12 additional attributes that NASP derived vehicles (NDVs) offer. Shown in Table 7, these attributes more clearly depict the capabilities such a vehicle would have and why it is seen as offering a revolutionary impact for the Air Force.

The top NASP technical challenges are in two major categories: airframe and propulsion. The Air Force and NASA have established confidence factors for each technical area which give indications of how the research, development, and concept validation is progressing. In addition they forecast confidence factors for 1990 which are based on assessments by their program managers on which areas, if any may delay a Phase 3 full-scale engineering and development decision. Confidence factors for each area are shown in Table 8.

Table 7.

Attributes of NASP Derived Vehicles [3]

Assured Access	Responsive Access	Flexibility
element of a mixed fleet	on-demand takeoff	all azimuth flight
reliability of aircraft	rapid turnaround	ascent plane change
all-weather flight	horizontal processing	safe abort
standard runway basing	containerized payloads	self ferry

Table 8.

NASP Technical Challenges and Confidence Factors[4]

	1986	1988	1990
Airframe			
Structures and Materials	R	Y	B
Thermal Management	Y	G	B
Flight Vehicle Integration	R	G	G
Inlet/Nozzle Performane	R	Y	G
Slush Hydrogen	Y	Y	G
Propulsion			
Ramjet	Y	G	B
Scramjet	-	-	-
Thru Mach 12	Y	G	B
Above Mach 12	R	Y	Y
Rockets	Y	G	B

Lowest Confidence R Y G B Highest Confidence

It is important to note that the trend for scramjet propulsion above Mach 12 was rated as a lowest confidence area in 1986. It is higher today, but not projected to change through 1990.[5] As such this area can be singled out as a limiting technology and perhaps even a no-go determinant. Given time, Air Force program managers are confident the technology can be mastered. The uncertainty of when such scramjet technologies will be available then becomes a major variable in projecting the utility of NASP derived vehicles through the year 2000. In addition other technical uncertainties are sure to exist; however, most have been identified as major program challenges by the Air Force.[6]

The NASP derived vehicles are envisioned to be concurrently developed with the NASP program as major milestones are completed. The concept of development is important to understanding the future of NASP since the concept itself presupposes the ability to transfer the NASP X-30 technology directly to the NDV S-30 program at the system development stage. In effect, the technologies will still be maturing and expanding as the first generation of S-30s become operational. Figure 6[7] shows the current development concept and maturation process. The uniqueness of this diagram is that as an operational capability is brought into being, the technology transfer and pre-planned product improvements (P3I) will most likely begin to counterflow back to the X-30 program much quicker than they have for other advanced technological programs. This approach offers both increased initial risk and accelerated technological expansion of systems at the expense of first generation operational capability. For the purpose of this study, this increased risk, and potentially limiting first generation capability, suggests that although the NASP program and resulting NDVs are revolutionary in concept their actual employment might be along more evolutionary lines. Regardless, the NASP program has important short- and long-term implications for virtually every aspect of the DODs future in space.[8]

The potential program schedule for NDVs is shown in Figure 7.[9] It envisions three NDVs dedicated for space operations early in the 2000s. Concurrent with these three vehicles, two X-30s and the initial two S-30s will be dedicated to technology development, operational testing, and engineering. Should the program proceed as depicted, these three operational vehicles offer a routine access to space sufficient to place in-orbit the majority of medium- and light-weight SDI components, as well as many other launch requirements.[10] Past Rand Corporation assessments on the NASP program have stressed the political vulnerabilities of the program and, as such, offer an additional consideration for this study.[11] To date, however, the program is continuing to receive the political support necessary and has not been the focus of budget reduction efforts.

In concluding this section, NASP and NDVs offer revolutionary capabilities and will most likely provide, in an evolutionary way, the DoD with an assured access to space. The proliferation of the NDVs as a Block II production option will necessitate basing options and large complex support structures and systems, but not in an extensive manner. Perhaps the biggest impact will exist in the ability they will offer to aggregate large volumes of materials in space for space construction purposes. Additionally, the hypersonic cruise capability they generate may result in the operational deployment of the next generation of fighter, bomber, and transport aerospace craft in the decades that follow 2010.

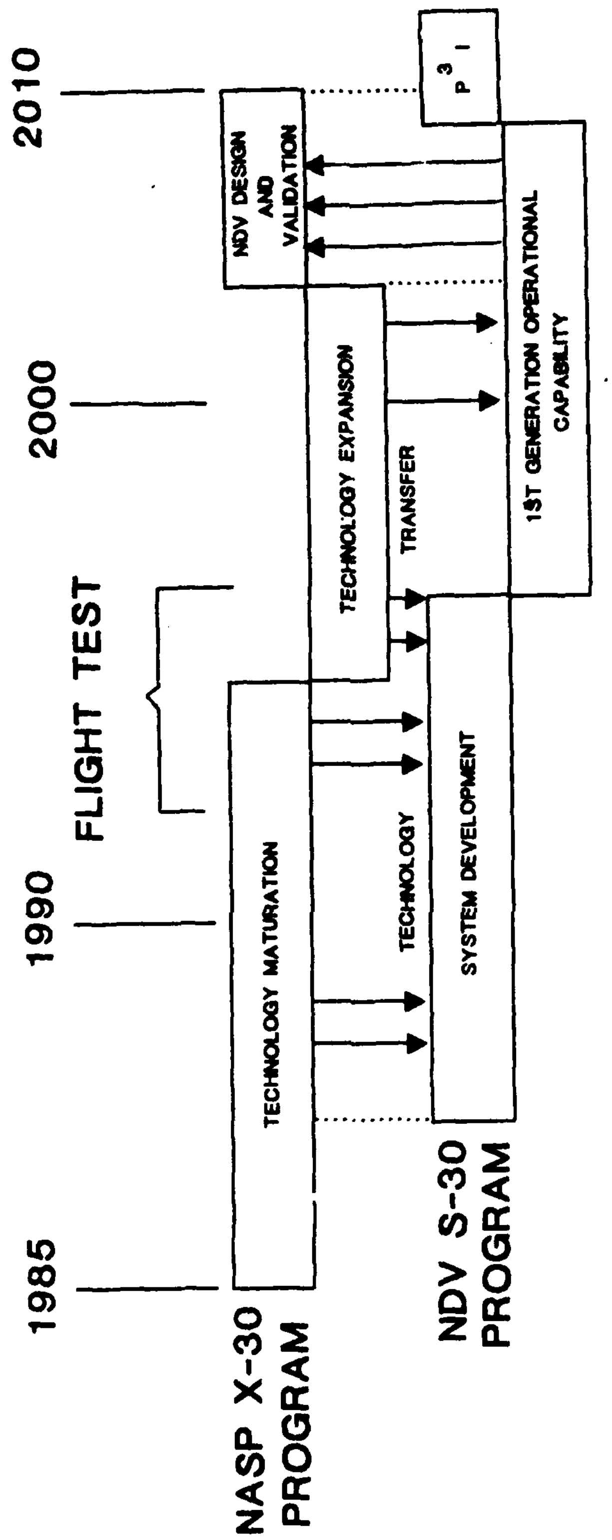

Figure 6. NDV Development Concept and Maturation Process*

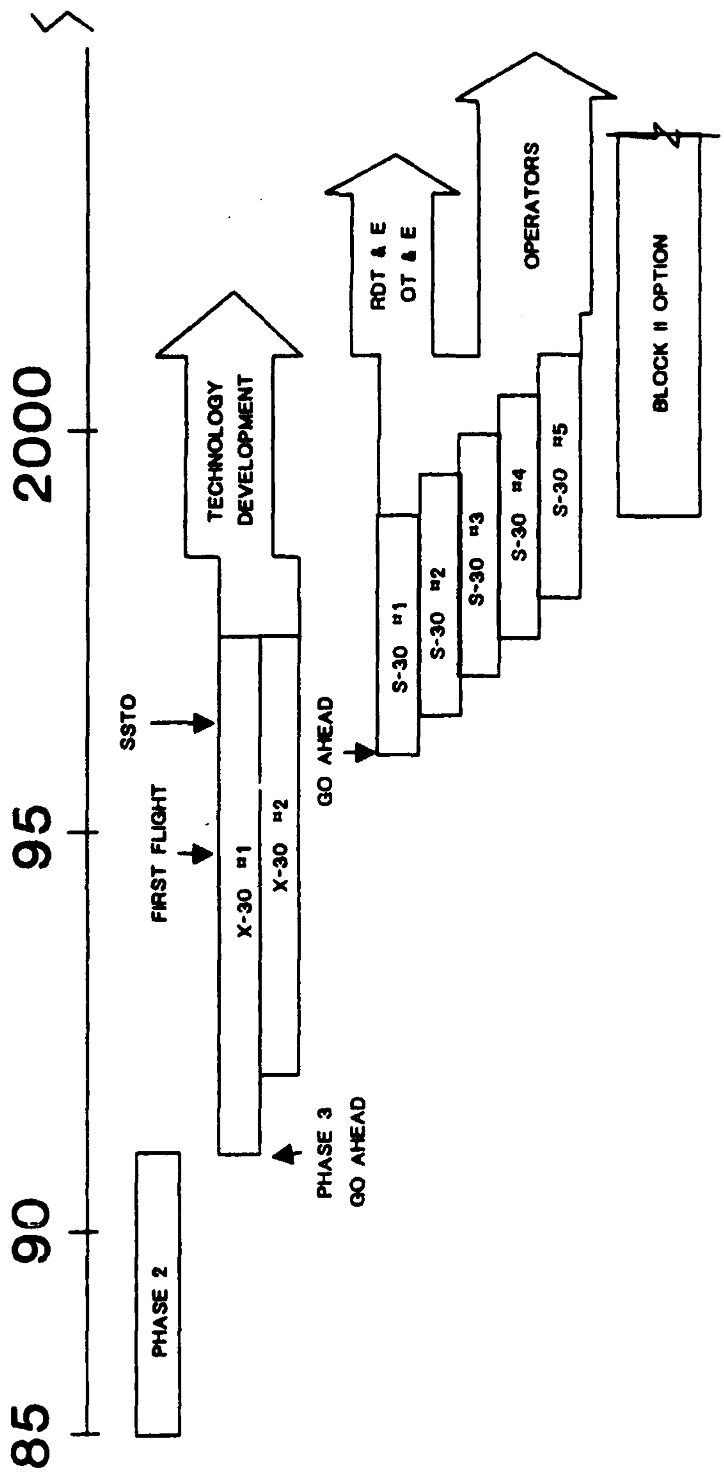

Figure 7. NDV Program Schedule.

CONTROL AND WEAPONRY

Previous chapters have established the national security imperatives of space control. Additionally, the space control systems center on the SDI, BMD, and ASAT technologies. It is, generally, agreed that the SDI has moved rapidly forward since its announcement in 1983, and will continue to do so. Much like transportation technology there are enabling technologies for the SDI and space control in general. Open sources discuss a few such technologies as rapid information processing made possible by very high speed integrated circuits (VHSIC) and artificial intelligence (AI) technologies. To emphasize the need for wide-spread focused attention on these types of technologies and the whole topic in general, the Armed Forces Communications and Electronics Association, recently proclaimed space as its new frontier.[12] A host of programs characterize space control and weaponry today. They include space-based radars using gallium arsenide integrated circuits,[13] space-based nuclear generators using magneto-hydrodynamic transfer technologies,[14] satellite detection and tracking systems using Teal-Ruby staring arrays[15] and submarine communications using orbital lasers.[16] The proliferation of research and development technologies associated with space control is so vast that it is difficult to identify any limiting or pacing programs. Figure 8 is a matrix of 16 advanced technologies, five categories of evolving weaponry, and three categories of potentially revolutionary weaponry. The relationships shown as a result of the matrix indicate how complex and interdependent future weaponry is in respect to their enabling technologies.[17] Therefore in characterizing the technologies and systems of space control and weaponry, it is possible to project both evolutionary and revolutionary capabilities.

A good example of a revolutionary weapon is the recently announced Brilliant Pebbles program, identified by Aviation Week and Space Technology as a potential SDI system.[18] A light-weight, compact, low-cost interceptor which has high-resolution optics using multiple charge-coupled devices (CCDS), offers revolutionary potential for the SDI. Conversely, the Exoatmospheric Reentry Interceptor System (ERIS), being developed by the Army for the SDIO, takes kinetic energy weapons to their next evolutionary step and offers promise as an ASAT system.[19]

The nature of space control and its vital role in national security will demand technically advanced solutions in the future. The programs that are underway and being advocated today will, to a large degree, distill themselves as their utility and urgencies are debated by defense officials. For this study, however, it should be recognized that revolutionary technologies exist and that given their successful application they will help shape force structure decisions and military activities well through the year 2010.

Figure 8.

POTENTIAL WEAPONS AND THEIR ENABLING TECHNOLOGIES TO 2025		High resolution optics	Artificial intelligence	Ultra high speed data processing	Advanced computer architecture	Advanced composite materials	Active stealth systems	Kinetic energy (weapons)	Autonomous guidance systems	Directed energy (weapons)	Robotics	Computational fluid dynamics	Space platforms	Thermal control	Systems integration & design	Advanced fuels
Realtime multi-spectra satellite sensors	EVOLUTIONARY 1990-2025	■	■	■	■								■			
Stealth platforms						■	■					■		■		■
Precision guided munitions		■		■		■	■	■	■	■	■				■	
Battlefield robots		■	■	■	■				■		■				■	
Hypersonic vehicles				■	■	■	■		■			■	■	■	■	■
Aerospace control	REVOLUTIONARY 2010-2025	■	■	■	■		■						■	■	■	
Multi-tiered defense system		■	■	■	■		■	■	■	■			■			■
Multi-tiered offense system		■	■	■	■		■	■	■	■			■			■

POWER

The third technological area is as vital to the Air Force's future in space as the first two areas, however, successful application of power as a space technology is necessarily dependent on the first two. For example, in the case of space control as an element of policy, the SDI represents a capability that can deny the use of space to enemy intercontinental ballistic missiles. Assured access to space through transportation technologies allows the deployment, operations, and maintenance of SDI assets which are in effect made possible by the technologies of control and weaponry. However, many of the control and weaponry systems are dependent on power available in space. In fact, all but two categories of weaponry shown in Figure 8 show power generation as an enabling technology. Clearly then, power, while not an absolutely fundamental technological area of space research, is at the very minimum a necessary co-requisite technology. In regards to probable impacts of space on Air Force Civil Engineering, it is in fact a vital area to review, since power generation or the provision of power for Air Force missions is a traditional civil engineering responsibility.

Space stations, manned and unmanned platforms, directed energy weapons, satellites and space-based information systems are just a few space activities that will require power. Chapter III presented NASA's long-range plan for development of power generation in space (Table 5). Turn of the century power requirements for the space station are all projected to be in excess of 200 kw. Future systems will be either nuclear or solar and are evolutionary with respect to earth technologies. Additionally, they are projected to be able to provide the needed power requisite with the maturing technologies requiring the power.[20] The topic is not without issues however. In the case of solar, the solar arrays deliver power at relatively low voltages and with unacceptable fluctuations. Research is under way to develop power processing systems which can help by synthesizing alternating current from direct currents supplied by solar arrays. Power storage systems are also being developed along with power controls to provide greater and more stable capacities. In the area of nuclear generation the issues concern, efficiency in converting thermal power to electrical power, radiation shielding of manned f ilities, and possible contamination due to inadvertent early re-entry of space based plants. None of these issues are reportedly beyond the reach of technological solution.[21] Therefore it is possible to characterize this area of technology as clearly evolutionary.

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ANALYTICAL SUMMARY

-Transportation technologies for expendable launch vehicles are evolutionary.

-The Advanced Launch System is a balance of proven and emerging technologies and is evolutionary in character.

-The NASP program offers revolutionary capability.

-The NDVs have attributes that offer to revolutionize access to space.

-Top NASP technological challenges have been assessed and confidence factors are projected to be acceptable in all areas except scramjet propulsion above Mach 12.

-Scramjet technology above Mach 12 can be identified as potentially limiting to the NASP program development and schedule.

-NASP and NDV technology transfers pose additional risks due to compression of the development and technology maturation process.

-Provided technological challenges are overcome three NDV's are scheduled to be operating by 2001.

-Block II production options on NDVs could revolutionize space flight for the USAF.

-Hypersonic aerospace craft are likely to be operating by 2010.

-Space control and weaponry technologies are evolutionary and revolutionary in nature, and are functions of many enabling technologies.

-Relationships between space control and weapons technology and their enabling technologies are complex and interdependent.

-National security imperatives in space demand advanced technological solutions to future space force structure decisions.

-Power generation is a vital enabling technology for many DoD and NASA space programs.

-Power generation technologies are likely to be either nuclear or solar source.

-Power generation technologies are maturing in space with their generation requirements.

-Power generation technological challenges do not present limiting factors to other space technologies or systems.

NOTES

1. The three areas referred to are transportation, control, and weapons and power. These technologies contribute to the development of systems which are essential to qualifying evolutionary trends or confirming revolutionary capabilities.
2. Yarnall, Briefing Notes, p. 35.
3. Briefing Notes, NASP Program Charter, November 1988, p. 8.
4. Ibid, p. 11.
5. Jim Martin, "Creating the Platform of the Future, NASP", Defense Science 1988, September 1988, pp. 55, 57, 60.
6. Briefing Notes, NASP Program Charter, November 1988, p. 9.
7. Ibid, pp. 2-5. This figure was created by superimposing the projecting program schedule over the program development concept.
8. Martin, "Creating the Platform of the Future, NASP" p. 55.
9. Briefing Notes, "NASP Program Charter," November 1988, p. 17.
10. Ray Spangenburg and Diane Moser, "NASP: Railway to the Last Frontier?" Space World, May 1988, p. 16.
11. Scott Pace, NASP Program: Principal Assumptions, Findings and Policy Options, Rand Corp., Santa Monica, CA, December 1986, p. 14.
12. "Space: AFCEA's New Frontier," Signal, September 1988, pp. 79-85
13. Ulsamer, The Military Imperatives in Space," p. 93.
14. Ibid, pp. 93-94.
15. Ibid, p. 95.
16. Ibid, p. 97.
17. Arthur L. Bennett Jr., Major, Command of the Aerospace: Convergence of Theory and Technology in Shaping an Aerospace Force for 2025, Air University Airpower Research Institute,

Maxwell AFB, AL, August 1986, pp. 22-25. In this report Major Bennett suggests a family of evolutionary and revolutionary weapons. He draws most of this information from a report by The Alternative Futures Panel, Air Force Innovation Task Force, CSAF, Washington DC, June 1984. The Alternative Futures Panel identified many weaponry concepts in its report some of which are not appropriate to Major Bennett's work, or this study. The relationships of the weaponry concepts and enabling technologies shown in Figure 8 are not presented as official information from the Air Force. The relationships are largely the opinion and research of this author.

18. Foley, "Brilliant Pebbles Testing Proceeds at Rapid Pace" p. 33.

19. Washington Bureau, "Pentagon Preparing to Restart Antisatellite Program in January," Aviation Week and Space Technology, November 14, 1988, p. 33.

20. Gordon R. Woodcock, Space Stations and Platforms, Malabar, Florida; Orbit Book Co. 1986, pp. 81-86.

21. Ulsamer, "The Military Imperatives In Space," p. 93.

CHAPTER V
SUPPORT CONCEPTS

This chapter addresses three key topics in the general area of support concepts. The topics, logistics, engineering, and space facilities form a natural grouping in both the traditional vernacular of the Air Force and in regards to space. Commonalities among the three topics include concept formulation, engineered solutions to requirements, similar technological bases, fairly traditional support roles focused on operational capability and co-requisite priorities. In respect to space, logistics, engineering and facilities can be considered as lagging behind the developmental and operational sectors of the Air Force primarily due to inattention to the development of support concepts. USCINCSPACE General John Piotrowski suggested the problem exists by saying, "I believe the current US space systems are a fragile, thin blue line. (It is) a thin line not sufficiently backed by on-orbit spaces or a rapid replenishment capability."[1] Conversely, it can also be argued that the research and development (R&D) and operating commands have virtually ignored the historically significant role logistics have played in modern military affairs.[2] Further, there is evidence to support the idea that what support efforts do exist today are largely due to far-sighted logisticians forcefully inserting themselves and ideas into the R&D world.[3] Regardless of the past, the time has come for Air Force logisticians and engineers to actively engage the imperatives of space.

LOGISTICS

In direct support of current Air Force space policy, the Air Force Logistics Command (AFLC) has recently begun the strategic planning necessary to normalize its roles in space.[4] In its initial effort, AFLC identified organizations, people, leadership, track records, and management as broad areas in which to focus its attention.[5]

In deliberations on these areas, several subareas were highlighted which have important implications. In the area of organizations, the lack of clearly defined organizational structure contributes to confused lines of communications and fragmentation of effort. In the area of people, training, resource management, and retention were key subareas which aggrevate the institutionalizing and normalization of space. In the leadership area, the lack of logistics guidance in space related program directives results in undesignated support command responsibilities. Last, in the management area, inattention to space system technologies and the uncontrolled use of nondevelopmental items (NDI) contribute to serious logistics support deficiencies in virtually every segment of space.[6]

The overarching p mise that AFLC has adopted in overcoming the above problems is simply that AFLC can improve logistics support to space by reducing it to a routine function.[7] To date, a clear understanding of its historical support, current posture, trends and developments, alternative futures and issues, and concerns is being developed for all segments of space. With this as a foundation AFLC, will begin its irreversible trip forward into space.

Although AFLC is just beginning its efforts in space, this doesn't mean there hasn't been any significant efforts in the area of space logistics. In fact there has been, in the past year, several excellent support concepts and studies published which provide very useful information for this study. One particularly good article is <u>A Support Concept for Space-Based SDI Assets</u> by Major Neal M. Ely.[8] Some of the points Major Ely makes have important implications for the SDI program, as well as for space logistics. In effect, he argues that the baseline SDI architecture of space-based interceptors, directed energy weapons and boost surveillance and tracking systems presents groups of constellations in low-earth orbit and geosynchronous orbit so numerous that orbit lives of 10 to 20 years are essential to keep overall costs manageable. This 10-year to 20-year service life is the driving requirement for the space-based concept of support.[9] The concept itself is a fairly simple initial six-element integrated system, based on space assets being modular, standardized and composed of orbital replacement units (ORUs). Organized around the first element, a space based support platform (SBSP), the remaining elements are a hydrazine tanker, a telerobotic servicer, an orbital transfer vehicle (OTV), an orbital maneuvering vehicle (OMV) and ORUs. When compared with actual systems being developed by NASA, the concept takes a very big step toward reality (Table 9). It should be noted that most of the NASA support systems are in effect precursors of DoD systems, and as pointed out several times in this study, the migration of these technologies to DoD is inevitable and called for by National Space Policy.

An important concept to note from Table 9[10] is that a space-based concept of support is well on its way to being developed. The adoption and furtherance of the basic technologies and advocacy of generic support program such as OTVs, OMVs, and FTSs could help bring the logistics community up to speed with the main stream of space activities. Several other studies support space-based logistics programs. In a recent report on on-orbit servicing and repair, Major Linda S. Wyatt asks such questions as when such a program is needed, how should space assets evolve to allow simpler servicing, and what roles will the space station and space shuttle play?[11] The answers Major Wyatt gives all support an unquestionable need to institutionalize space logistics and bring into being on-orbit capabilities. Another recent article in Logistics Spectrum, by George E. Herring, a program manager for the Space Division of General Dynamics,[12] outlines a similar space-based support concept as shown in Table 9. He advocates the need for the entire space industry to come to grips with the logistics questions by standardizing and modularizing space assets thereby making the ORU concept more feasible. He summarizes by emphasizing that the "fly-to-failure days" of space assets are over and that the nation's increasing dependence on space for national security demands space logistics capabilities coequal with the space systems they support.

An emerging set of support technologies, some being developed by NASA, link logistics, engineering, and space facility capabilities together. Emerging primarily as a result of the user interest in space logistics, they include robotic servicing, component replacement item theory, fluid storage and transfer, extravehicular activity systems and large structure assembly technologies. These basic areas have important subareas that will, to a large degree, determine the characteristics of space logistics and space facility engineering in the future. These families of technologies are shown in Table 10.[13] The list of subareas is virtually endless; however, the items shown give a good indication of how pervasive the support technologies will become. The broad implications for space logistics, in general, seem to support an evolutionary label for today's capabilities with a clear need to revolutionize the entire spectrum of space logistics.

Parallel to emerging support technologies is the role of military men in space (MMIS). The short history of space development can, in some respects, be characterized as an elusive search for the role of MMIS. These are evidence, however, that the formalization of a permanent role for man's presence in space is happening. A recent study by an Air Command and Staff student concluded that a role in space is finally gaining support, and that the development of a national space station and the NASP will provide the platform and transportation which will finally counter the arguments that man's permanent presence in space was not worth the risks to life that have dissuaded a permanent presence to date.[14] The primary roles of an MMIS include the construction and maintenance of large space-based early warning radars, maintenance of command, control and tracking systems, operating and maintenance of space stations, on-orbit maintenance and depot ORU operations, support for SDI and many more. The support role that the issue of MMIS seems destined to fill is very important to this study, especially when coupled with the potential uses of a space station, as related to Congress, by former Defense Secretary

Carlucci.[15] Like support technologies, the MMIS provides a unifying link across the entire spectrum of space support concepts.

Proposed SDI-Support Concept*	NASA Support Architecture	SDS Compatible & By Need Date (Phase I)
-Space Based Support Platform (SBSP)	-NASA envisions using the aft deck of the shuttle initially and later a polur orbiting platform (POP)	yes to a limited degree
-Orbital Transfer Vehicle (OTV)	-OTV's several concepts of development. First flight 1995	yes with modifications
-Orbital Maneuvering Vehicle (OMS)	-OMV in design and production by TRV. First flight 1993	yes with modifications
-Telerobotic Service	-Flight telerobotic servicer (an ORU exchanger) (FTS). Preliminary version by 1993-1994	yes, leading to autonomous capabilities
-Hydrazine Tanker	-Orbital spacecraft consumable resupply system (OSCRS)-a monopropellant tanker. First flight 1995-1996	could be useful
-Orbital Replacement Unit (ORU)	-ORU technology and design is currently employed in the NASA OMV & Hubble Space Telescope	basic technology is transferrable
-Others (beyond an initial support concept these could be useful)	-Cryogen refueling tanker (CRTR). Proposed by 1996	could be useful
	-Superfluid helium on-orbit transfer capability (SHOOT). First available 1991	could be useful

*This concept is essentially a Space Asset Support System (SASS)

Table 9. Comparison of SDS Support Concept with Current NASA Program. [10]

Table 10
Space Logistics and Engineering Technologies[13]

Basic Areas	Subareas
Robotic Servicing	-telerobitcs, sensing, perception, effectors, operator interface, system architecture, time delay data links, autonomous operations, artificial intelligence, supervisorial robots.
Component Replacement Items	-ORU storage points, ORU satellites, thermal self-sufficiency, built-in test for fault diagnostics, fault tolerance capabilities, redundancy management, hardening, and maintainability consideration.
Fluid Transfer and Storage	-fuel storage units, pump and transfer couplings, liquid/vapor separation units, cryogen boiloff protection, flow management controls, contamination containment systems, and quantity measurement systems.
Extravehicular Activity	-assembly systems, specialized, universal tools, damage resistant space suits, miniaturized breathing and propulsion systems, EVA work stations, cluster, branch and planar connectors.
Large Structure Assembly	-maintenance and assembly of electro-optical and reflective surfaces, sure fit electrical connectors, grappling attachment systems, truss fabrication machines, advanced zero-g structural dynamics, configuration design and integration.

ENGINEERING

In its broadest sense, space is the world of high technology and new frontiers conquered by the vision of men and their creative abilities to build spacecraft and space systems and facilities. In another sense, it is the technical engineering capacity of the US that has made space what it is today.

In the area of support concepts, engineering could present not only the limits to capabilities but the very activities as well. The Air Force Scientific Advisory Board, in 1983, concluded that the development of space facilities, technologies related components, systems and sensors could best be advanced by a manned presence in space.[16] In fact simply "taking the high ground in space" has been rejected in the past by Congress as an acceptable argument for funding permanent manned programs.[17] Engineering can be thought of as the glue that holds space requirements and capabilities together. For these reasons then, it is important to understand the impact space support engineering presents to support concepts.

As pointed out in Table 10 there exists a growing requirement for technological development in the areas such as robotic servicing, component replacement items, fluid transfer, and others. What is of importance to this study, however, is the need for these technologies have found its genesis in operating requirements.[18] Support concepts alone have been unable to generate sufficient recognition in and of their own importance; therefore, their technological development status is not only lacking but subservient to operational requirements. In short, the space support engineering committees have failed to recognize the potential that the medium of space offers, as well as the truly revolutionary nature of space as a theater of operations from the force enhancement standpoint. In fact, the recent efforts by service logistics communities to define support concepts, and thereby requirements, suggests that space support engineering today remains largely a NASA activity.[19]

The notions of platforms, stations, and facilities in space suggests that space support engineering is quickly transforming itself to a more direct operational role. Unlike airbases, the stations and platforms are not currently envisioned as simply launch platforms for weapons, but observation stations, logistics nodes, and technical research laboratories.[20] Also, peculiar to space is the notion that unlike terrestrial facilities the life support systems required in space are in and of themselves complex, technically demanding, and vital for manned presence. All of these aspects of facilities in space necessitate that the space support engineering communities prepare themselves for key roles in helping the US realize its full potential in space.

FACILITIES

With the linking elements of military men in space and space support engineering, the next focus of this chapter is space facilities. For the purposes of this study, space facilities are defined as everything in space that is not a satellite or an element of transportation. In current technical language, this would exclude the STS, NDVs, OMVs, OTVs, and the most satellite systems. Some elements of satellites, such as solar arrays, antennas, structural components, and housekeeping ORUs of the future can be considered as exceptions to this definition. In addition to space facilities, or space based facilities, there is a set of space related facilities based on the earth. These are most often simply described as ground-based facilities. Regardless of the location of the facilities, all are the object of three distinct operations which military facility engineers perform.[21]

First is the provision of the facility governed by planning, design, construction, or fabrication and acceptance functions. Second is the operation of such facilities, which generally entails the provision of utilities and actions which activate, engage, disengage, regulate or otherwise control systems and subsystems of the facility. Third is the maintenance of facilities which includes a range of functions from simple part repair or replacement to depot level major system and subsystem exchange, repair or remanufacture. Returning back to the discussion of space logistics, it seems that the only real difference between the functions a space logistician might perform and those of a space facilities engineer lies in the way one defines the space asset. Currently, there are four basic categories of space assets: vehicles, satellites, weaponry, and platforms. Traditional thought indicates that the latter category, that of platforms, will eventually become the pervue of facility engineers especially if they function as habitats, working space or laboratories for humans and in the case of unmanned platforms are clearly not vehicles, satellites or weapons. Regardless of who maintains, operates or provides space assets, it is once again important to note that with the exception of providing and operating vehicles, satellites and weapons, the space logisticians and engineers have a very significant role to prepare for.

Some evidence exists that such preparations are underway. As indicated in Chapter II, the Air Force Space Policy is visionary enough to foresee the eventual role that space facilities may play; however, it lacks the necessary link with the larger space logistics concepts which define its broader relationships with vehicles, satellites, and weapons.[22] None the less, there have been technological advances which should not be overlooked. In a NASA report prepared by a contractor regarding human performance issues and space facilities, a lot of important concerns were identified.[23] Some of them are the lack of, and important utility of multipurpose tools, the omission of simple approaches such as double sided sticky tape, dissimilarities in training at 1 gravitational force (G) versus zero-G, blackbox level maintenance, complexity of maintenance instructions, routine maintenance by humans versus redundant and automated systems, and numerous more. Other issues even more universal include the need for privacy and alone time by crews, the aesthetic needs of man in constant interface with machines, crew members and fitness in zero-G environments, safety hazards and design of space suits, and the full utilization of a crew member's intellect versus task rigidity and lock step methodology. These concerns and issues are indicators that the needed attention to space facilities and engineering in support operations is only just beginning to happen. In another technical report by the Air Force Rocket Propulsion Laboratory on large space system design, it was suggested that space facility engineers have basic requisite skills in advanced computer-aided design and nongravitational structures theory.[24] This particular report titled Large Space Systems Design was initiated by the Air Force to further develop the knowledge base and understanding of large space structure directional control, vibration and construction. The report is a superb example of the Air Force's need to focus attention on engineering and technology in the area of space facilities. Other similar studies are listed on Table 11.[25] Some important implications can be drawn from these studies.

First, the dynamic nature of space structures involves complex engineering calculations very different from the structural design of facilities on earth. Second, the nature of zero gravity structural analysis requires construction or assembly methods dramatically different from these on earth. Third, that space facilities design must start from a point in space about which total dynamic flexibility exists versus fixed-land assets. Fourth, that vibration analysis and torque control have radically different theories in relation to space. These are but a few examples of how different space structures and facilities are from a design engineer's perspective. What this may, in fact, suggest is that facility engineers in space will have to equip themselves with a highly specialized set of additional skills to those needed for terrestrial based requirements. This is not to say that space is so unique that it presents insurmountable problems. A 1985 article entitled Frameworks for the Future discusses a NASA program called Experimental Assembly of Structures in Extravehicular Activity (EASE) and Assembly Concept for Construction of Erectable Space Structures (ACCESS).[26] Both EASE and ACCESS have successfully demonstrated many of the skills needed for assembly of the national space station. As with space logistics, both EASE and ACCESS have important implications for the Air Force in regard to space facilities. The experiments emphasized the need for designing tools and components in ways that allowed easy manipulation by suited astronauts. Construction methods present equally demanding considerations when coupled with a need for high efficiency due to limited construction times which are necessitated by the harsh environment and microgravity. The initial EASE on-orbit experiments have paved the way to more complex tasks. Another important aspect was the fact that when following in-depth time-motion videotape analysis of each construction effort, it was universally agreed that the human ingenuity, the timely on-the-scene judgments, and the ability to provide instant feedback will be essential to future space construction efforts.[27] This is perhaps a key differentiating aspect between satellite servicing in space logistics and facility engineering.

NASA has also led the way in other areas of space structures and construction. The Howard Large Space Structures Institute (LSSI) in Washington, DC has been involved in creating a body of knowledge for the advancement of structural analysis, dynamics, and control of space structures for NASA since 1982.[28] The Air Force has also sponsored, at Howard, research into computer graphics and software development for space-related construction through the institute's Department of Civil Engineering. The contributions contractors such as LSSI and others are making represent to some degree a whole new field of engineering that facility engineers responsible for space stations, platforms, and other such structures will need in the performance of their duties.

Table 11.

Large Space Structure Research and Engineering Studies

Large Space System Deployment Dynamics

An engineering methodology to develop an analytical model to predict and simulate the dynamics of large flexible space structures during deployment

Deployment Dynamics Software Development

A general computer program simulation of the deployment dynamics of large flexible spacecraft

Ada Based Real Time Control Software

The creation of a library of Ada based functions to be used in the construction or programs to control the dynamics of large space systems

Linear Torque Slew Control

An engineering feasibility study of using on-off thrusters in conjunction with control-moment gyros (CMGs) and proof/mass actuators (PMAs) to slew a large space structure

Piezoelectric Distributed Actuator

An engineering feasibility study of using a thin piezoelectric polymer sheet as a distributed active structural vibration damper and shape sensor for large space systems

The body of knowledge concerning space structure design and construction is developing at almost revolutionary speeds. Only 1 year after the EASE and ACCESS missions, detailed textbooks on systems and subsystems for space stations and platforms began appearing. One such textbook, "Space Stations and Platforms," published in 1986 provides an indepth account of the NASA space station.[29] It begins with an overview of the stations conceptual development and functions and ends with highly detailed system schematics, diagrams, plans, and calculations that provide a superb understanding of the program and its technology. Such texts represent the beginning of a new era for space facilities and engineering, as well as for the entire subject of space support concepts.

To summarize this chapter then, it can be said that space logistics as a support concept, while initially left unattended, has in the past year come to grips with many of the challenges preventing its evolutionary growth parallel with operational space programs. Further, the imperatives of space support logistics have been recognized, and the continuing technology transfer of support architecture from NASA will help revolutionize space logistics capabilities as space logistics itself seeks a normalized role in the Air Force logistics communities. In regard to MMIS and space engineering, these fields represent the fabric which binds space support and operations together as well as links space logistics to space facilities. The MMIS issue may finally find a source of resolution through the demonstrated need of man-in-the-loop space logistics and space construction. This resolution may offer revolutionary possibilities for space logisticians and engineers. Finally, in the area of space facilities, enormous potential for change may revolutionize facility engineering by creating a requirement for a special cadre of space facility engineers with specialized skills and education unique to the planning, design, construction, assembly, fabrication, operation, maintenance, and sustenance of space facilities.

ANALYTICAL SUMMARY

- Commonalities among space logistics, engineering, and facilities exist. Some of them are concept formulation, engineered solutions to requirements, similar technological bases, tradition support roles for operational capability, and co-requisite priorities.
- Space logistics and engineering lag behind operational sectors of space due to inattention to support concept development.
- Historically important roles of logistics in modern warfare have not been fully realized in space.
- Visionary space logistics engineers are attempting to advocate recognition of the importance of logistics in space.
- HQ AFLC is attempting to normalize its logistics role in space.
  - -- People, leadership, track record, and management are the areas which AFLC has focused on.
  - -- The absence of clearly defined organizational structures contribute to confused lines of communications and fragmentation of effort in AFLC.
  - -- Training, resource management, and retention of personnel place limits on AFLC's ability to normalize its space role.
  - -- The absence of logistics guidance in space program directives results in undesignated space support responsibilities.
  - -- Inattention to space system technological growth contributes to space support deficiencies.

-- Uncontrolled use of nondevelopmental items contributes to over reliance on contractors for logistics.

- HQ AFLC is attempting to meet AF Space Policy guidance in its attempt to make a routine function of space logistics.
- Excellent space support concepts exist for SDI.
- Space logistics concepts can be extended to space facility support concepts due to their common technical requirements.
- NASA has several support concept technology programs that have direct utility for the USAF.
- The basic NASA support architecture technologies will be operational by the middle of the 1990s and earlier.
- Long life space assets require on-orbit maintenance due to fiscal economies identified in life-cycle cost analysis.
- A key requirement for space logistics is the standardization and modular design of space assets and their components.
- National security imperatives of space demand an end to fly to failure mentality of the past three decades.
- An emerging set of space support technologies exist, and follow:
  -- Robotic servicing
  -- Component replacement item theory
  -- Fluid storage and transfer
  -- Extravehicular activity systems
  -- Large space structure assembly
- Subareas of basic space support technologies are extensive.
- Space support technologies have the potential to revolutionize space logistics.

- National programs to build a space station and an aerospace plane (SSTO) provide missions for a continued presence of military men in space (MMIS).
- MMIS and space engineering link space logistics and space facility support concepts.
- Space engineering is a vital mission for MMIS.
- Space engineering is a key activity in translating space requirements into space capabilities.
- Space support bears an equal priority to space operations.
- Growth in the development of space support concepts could revolutionize space force enhancement within DoD.
- Space facilities will operate as logistics nodes, observation platforms, and technical laboratories.
- Space support engineers will play a key role in space.
- Space support engineers will provide, operate, and sustain space facilities.
- AF Space Policy is visionary and foresees eventual roles of space facilities but does not link operational and logistical space requirements.
- Important human performance issues exist in space operations.
- Attention needs to be focused on resolving human performance issues for the advancement of space logistics.
- A body of knowledge about large space systems and structures is being developed by NASA and the USAF.
- Attention in the area of engineering technology is needed for further development of space facilities.
- Space and terrestrial facility engineering are radically different.
- Space construction materials and methods have been the focus of limited NASA and USAF research and development

since 1982.

- The potential exists that a whole new field of space facility engineering will emerge.
- Space facility technology is developing in a revolutionary manner.

NOTES

1. Letter "White Paper on AFLC, Space Logistics, Issues, and Options," HQ AFLC/XP, 7 December 1988, p. 2.
2. The tooth to tail ratio arguments are generally accepted throughout the history of modern warfare. General research supports the concept that the higher the technology of the weapon system the more removed it has become from the general support structure of the services
3. Three such studies are: Neal M. Ely, Major USAF, "A Support Concept for Space-Based SDI Assets," AF Journal of Logistics, AFRP 400-1 Vol XII No 1, Winter 1988, pp. 17-21; David B. Willie, Capt, USAF, "Space Logistics Technology; The New Challenge," AF Journal of Logistics, AFRP 400-1 Vol XII, No 3, Summer 1988, pp. 30-34; George E. Herring, "Product Support and Maintenance for Space Based Systems," Logistics Spectrum Vol 22, Summer 1988, pp. 37-40.
4. Letter, "White Paper on AFLC Space Logistics...." pp. 2-22.
5. Ibid, pp. 19-21.
6. Ibid, p. 5.
7. Ibid, p. 2.
8. Ely, "Support Concept for Space Based SDI Assets"
9. Ibid, p. 17.
10. Data for the SDI Support Concept is taken from Ely "Support Concept for Space-Based SDI Assets," pp. 18-19. Data for the NASA support architecture is from Congressional Hearings, NASA's Long Range Plans. Referenced in Chapter III.

11. Linda S. Wyatt, Major USAF, "On-Orbit Space Maintenance," student report, Air Command and Staff College, Maxwell AFB, AL, April 1987, pp. 1-30.

12. Herring, "Product Support and Maintenance for Space-Based Systems," pp. 38-89.

13. General research in the area of space logistics identifies these five basic areas as categories of logistics technology needed for space support. The subareas which correspond to each basic area have application across the entire spectrum of general space support and operations. The listing is only suggestive and should not be considered as including all existing or potential requirements.

14. Timothy D. Killebrew, Major USAF, "Military Man In Space: A History of Air Force Efforts to Find a Manned Space Mission," student report, Air Command and Staff College, Maxwell AFB, AL, pp. 50-59

15. "Potential Department of Defense Use of Permanently Manned Space Station," Space Policy, August 1988, pp. 265-68.

16. Killebrew, "Military Man in Space..." p. 52.

17. Ibid, p. 54.

18. Letter, White Paper On AFLC Space Logistics....., pp. 7-13.

19. The three previously referenced articles by Ely, Willie, and Herring, and the HQ AFLC White Paper on Space Logistics reveal a surprising lack of depth on the issue. It is generally accepted that space support concepts are just now beginning to command the appropriate attention of service leadership.

20. Gordon R. Woodcock, Space Stations and Platforms, with a foreword by Edward G. Gibson (Malabar, FL. Orbit Book

Co, 1986), p. VII: "Potential Department of Defense Use of Permanently Manned Space Station," p. 266.

21. Major General George Ellis, "Briefing to the Space 88 Conference, Engineering, and Services Liason Group," 31 August 1988. In this briefing Gen Ellis emphasized the importance of the three traditional functions facility engineers have which are to provide, operate and sustain (maintain) facilities for the USAF.

22. National and DoD space policies mention transportation systems as elements of a space vision but do not make mention of logistical functions necessary for sustained development in space.

23. NASA, "Human Performance Issues Arising From Manned Space Station Missions," George C. Marshal Flight Center Contract NAS 8-35770, October 1986, pp. 1-58.

24. "Large Space System Design," Technical Report USAF Rocket Propulsion Laboratory, Edwards AFB, CA, October 1986, pp. 1-5.

25. Ibid, p. 21.

26. Tracy McMahan, Anna Shields, Valerie Neal, "Frameworks for the Future," Space Worlds, Vol V, November 1985, pp. 20-21.

27. Ibid, p. 23.

28. Ibid, p. 24.

29. Woodcock, Space Stations and Platforms, pp. 1-220.

CHAPTER VI
ASSESSMENT

The analysis presented in the preceding four chapters can be synthesized in several different ways. One way is to qualify each of the topical areas in relation to the research question, the probable impacts of space operations on Air Force Civil Engineering. This approach must necessarily define the fundamental mission areas of civil engineering in respect to the topical areas of space presented in the analysis. It must also identify the bounds in which the impacts fall as well as the timing of such impacts to be totally responsive to the problem statements.[1] This approach suggests that a linear relationship may be determined for each of the mission areas and analytical topics, which can then be discussed in terms of limits and time. This approach will form the first section of this chapter, linear relationships.

While it is important to understand the linear relationships of the study, it is also essential to codify the relationships as a whole, since they are also mutually interactive relationships that possess the potential to impact synergistically. For example, if we accept the analytical quality of the NASP as a revolutionary transportation system and the objective of HQ AFLC to normalize space logistics, then it is possible to project an accelerated space support concept of satellite servicing such that the shared space logistics and space construction enabling technologies allow earlier deployment of space capabilities for both areas than present programs call for. This approach will be the focus of the second section of this chapter, nonlinear relationships.

In order to limit or bound the assessment, it is essential to quantify and qualify the sets of activities which are the object of the study. General Ellis provided solid sets of activities to the Engineering and Services Space Liaison Group (ESSLG) at their second meeting in August 1988. In presentation, General Ellis identified three fundamental activities that comprises the facility engineer's mission.[2] They are to provide, operate and sustain facilities for the Air Force. Although not specifically identified, a fourth activity is that of maintaining facilities. It is a logical extension of sustaining facilities. For the purpose of this study all four activities will be discussed. The environment in which these activities take place form the second set of bounds for the study. Simply stated, facility engineers of the future will act on earth and in space, thus these parameters become fundamental activities in relation to earth and space environments.

As stated in the original problem statement, this research would limit itself to 20 years hence. In the course of the research, however, it has become prudent to extend the time boundary to 22 years or 2010. The obvious rationale for this appears in Chapters II and IV. Most of the technology assessments use the natural breaks in decades to divide time frames. In keeping with this convention, the limits for the assessment then become essentially the decades from 1990 to 2000 and 2001 to 2010.

LINEAR RELATIONSHIPS

The analytical model presented in Chapter I as Figure 1, suggests that similar to the GLCM example, the impact of space operations on civil engineering can be expressed in the form of vectors along a scale with minimum or maximum slopes indicating evolutionary revolutionary or radical potential. Throughout Chapters II, III, IV and V, where possible, such characterizations have been given to the topics in relation to space in general. Narrowing the focus of these characterizations is possible if the bounds of the study are presented as contextual limits. For example, the discussion on space control activities within the DoD, when factored with the fundamental facility engineer activity of providing space based facilities, can be characterized as having a revolutionary impact on status quo activities. Support for this characterization lies in chapters throughout the study, and follows this logical sequence. Space policy recognizes the national security imperatives of space control as a fundamental element of future global power. Space control encompasses space defensive and offensive systems. Space defensive systems may include assets deployed for periods up to 20 years. Long deployment periods of space assets necessitates orbital maintenance. Orbital maintenance may include requirements for manned and unmanned platforms or facilities in space. Therefore, the relationship of space control to the provision of space facilities is revolutionary since presently, there are no such facilities. Further support for this characterization appears in the discussion on space logistics which outlines the key initial technologies in relation to current NASA programs and their program schedules. Taken one step further, the technology and systems will exist to do orbital maintenance by the end of the next decade further qualifying the revolutionary potential by virtue of time compression

(Table 9).

Another such linear relationship is that of transportation and providing ground based facilities. The relationship is based on the following logic. The NASP offers revolutionary potential for assuring access to space in accordance with National Space Policy. Propulsion technology is potentially limited to achieving on-time flight testing of the NASP (Table 8). Mach 12 and above propulsion is possible, but may not be in place by 1995. Once in place, NDVs will be built. The operational concept of NDVs requires specialized support facilities for cargo containerization, fuel, maintenance, etc. It follows that a successful NASP program will require large complex facilities at more than one operating location and, therefore, offers revolutionary impact potential in terms of the provision of ground-based facilities and systems. If, however, propulsion technologies delay the anticipated NASP program then the facilities may not be required until late in the next decade. This extension of the time period tends to moderate the otherwise revolutionary impact. Consequentially characterized, then the relationship of space transportation to ground base facilities, factored over time, may be more accurately described as highly evolutionary.

A third linear relationship concerns the DoD force enhancement activities in space. DoD Space Policy recognizes the services' dependencies on space in the broad area of enhancing or multiplying the effectiveness of existing force structure with the aid of space assets. Satellites represent common force enhancement assets. Projections exist that state the number of satellites used by the DoD will triple by the year 2010. Control of satellites and their use as data links throughout the services will require facilities presently limited largely to AFSPACECOM. Therefore, a revolutionary impact of providing such high-technology facilities throughout the DoD can be anticipated. Taking this assessment one step farther, the ability to operate, maintain or sustain the projected satellite constellations may in fact, require facilities in space much like the maintenance facilities outlined for on-orbit maintenance of a space defense system. Taken as a whole the scope and timing of just one aspect of force enhancement suggests more than revolutionary impact, and can be said to characterize the relationship of force enhancement and virtually all of the facility engineer's fundamental activities as highly revolutionary.

In aggregate, the preceding analytical chapters comprise 25 topics. Compared with eight functional activities of facility engineers, there becomes two hundred such relationships like the three just presented. A discussion of each one is beyond the intent of this study. However, a characterization of each relationship is important to the study because it is the overall characterization of all of the topics with respect to the facility engineer's mission that will most accurately project the impacts which this study seeks. Figure 9 is a mission area and criteria weighted matrix which provides a characterization of each linear relationship. Conceptually it is similar to the analytical model shown in Figure 1. A general assessment of the matrix has yielded six summary statements concerning the relationships.

1) The space facility engineer's ground-based mission will most probably be highly evolutionary through the year

2020.

2) The space facility engineer's space-based mission will most probably be revolutionary through the year 2010.

3) Space policy will probably have moderately revolutionary impact on the space facility engineer's mission.

4) DoD and NASA activities will probably have a revolutionary impact on the space facility engineer's mission.

5) Space technology and systems will probably have a revolutionary impact on the space facility engineer's mission.

6) Space support concepts will probably have a highly evolutionary impact on the space facility engineer's mission.

If national security, policy, technology, organizations, their activities and requirements could realistically be reduced to numerical sums and linear relationships then this assessment could stop here. Obviously this is not possible, and a continuing assessment focused on nonlinear relationships, symmetries, and anomalies is appropriate.

MISSION AREA/CRITERIA WEIGHTED MATRIX

		SPACE POLICY						ORGANIZATIONS & ACTIVITIES											TECHNOLOGY & SYSTEMS				SUPPORT CONCEPTS				AVG
		- UTILITY OF SPACE	- IMPORTANCE OF SPACE	- NATIONAL POLICY	- DOD POLICY	- AF POLICY	- E&S POLICY	- DOD	- SPACE CONTROL	- FORCE APPLICATION	- FORCE ENHANCEMENT	- SPACE SUPPORT	- NASA	- PROPULSION	- ENTRY TECHNOLOGIES	- P.C. OF LARGE FLEXIBLE STRUCTURES	- POWER	- SPACE OPERATION	TRANSPORTATION	CONTROL	WEAPONRY	POWER	LOGISTICS	MMIS	ENGINEERING	- FACILITIES	
GROUND BASED SYSTEMS	Provide	-	-	2	2	2	3	8	8	7	9	7	3	8	7	5	2	3	8	5	4	3	5	2	2	4	5
	Operate	-	-	2	2	2	3	8	8	7	9	7	3	8	7	5	2	3	8	5	4	3	5	2	2	4	5
	Maintain	-	-	2	2	2	3	-	8	7	9	7	-	8	7	5	2	2	8	5	3	3	5	2	2	3	5
	Sustain	-	-	2	2	2	3	-	8	7	9	7	-	8	7	5	2	2	3	5	3	3	5	2	2	3	5
SPACE BASED SYSTEMS	Provide	9	9	9	8	8	6	8	8	9	9	7	8	9	9	9	5	5	8	10	10	4	8	7	7	8	8
	Operate	9	9	9	8	8	6	8	8	9	9	7	8	9	9	9	5	5	8	10	10	4	8	7	7	8	8
	Maintain	9	9	9	7	7	6	-	8	9	9	7	-	9	9	9	5	7	8	10	10	5	6	3	3	6	7
	Sustain	9	9	9	7	7	6	-	8	9	9	7	-	9	9	9	5	7	8	10	10	4	6	3	3	6	7
	AVG	9	9	6	5	5	5	8	8	8	9	7	6	9	8	7	4	4	8	8	7	4	6	4	4	5	

1	*SLIGHT CHANGE*
2	*MODERATELY EVOLUTIONARY*
3	*EVOLUTIONARY*
4	*MORE THAN EVOLUTIONARY*
5	*HIGHLY EVOLUTIONARY*
6	*SLIGHTLY REVOLUTIONARY*
7	*MODERATELY REVOLUTIONARY*
8	*REVOLUTIONARY*
9	*MORE THAN REVOLUTIONARY*
10	*HIGHLY REVOLUTIONARY*

Figure 9. Mission Area and Criteria Weighted Matrix.

NONLINEAR RELATIONSHIPS

Some of the nonlinear relationships that this section of the assessment will focus on have been alluded to by notable people with what one may describe as visionary concepts of what is happening to the military in respect to space. General Skantze's views in 1985, that the Air Force was reaching a "critical mass in space" and that its "technology search will propose among other things quantum leaps in space capabilities" have proven to be true.[3] One only needs to look at the status of force enhancement programs such as space based radar, or in the case of assured access, the NASP program, as evidence. Another such visionary, General Herres in 1985 stated, that the "country's national security depends on the high-tech edge of our space systems."[4] Alluding to the argument of space control as a determinant of global dominance, we have now seen international debate focused on the idea and sincere attempts on behalf of the Soviets to turn away from global dominance as a function of mutual assured destruction. A third visionary, General Piotrowski said, "a natural process of maturing space operations from a research and development orientation to an operational mode for employment of US space based resources is underway."[5] The preceding chapters are full of examples which support the views of Generals Skantze, Herres and Piotrowski. Of importance to this section of the study, however, is that these visions represent a converging set of influences in the military and that the full potential of the enormous impact they carry is yet to be felt.

Staying with this nonlinear notion, each general's vision can be found in the analysis portions of this study. General Herres' vision can be seen throughout the chapter on policy and clearly tied to space defense system programs. General Skantze's vision is evident in the chapter on organizations and activities and the linkage of DoD and NASA today. Last, General Piotrowski's vision is evidenced throughout the chapters on technology and systems and support concepts. What this may in fact suggest is that in assessing the analytical topics there is a synergistic efffect in their collective impact and that evolutionary or revolutionary labels assessed linearly are very conservative estimates of what the future holds.

It has been said that predicting the future is the work of the arrogant, because it is the arrogant who ignore what's pragmatic and have no fear of uncertainty. Pragmatically then, what has proven to be, out of the range of possibility, in any of the visions discussed above? The SDI is one element of space control which seems in question. Current literature suggests that a totally effective defensive shield is not possible. Suppose this is the case, does it cast aside the space control theory? Developing propulsion systems that enable single stage to orbit is blanketed with great deal of uncertainty. History tells us, however, that we can achieve the technology given the proper leadership and commitment. The Apollo Program stands as a tribute to that. The slow start in space logistics and space support concepts might be considered by some as an example of less than complete DoD commitment to space as the final frontier. However, this is changing rapidly as the values and mysteries of space are more clearly advocated.

There are those that say the budgetary requirements of space preclude its full utilization. There are also those that argue space is a zero sum growth situation, that traditional roles are giving way to space assets only as they become obsolete. Is the SR-71 an example of this? The Air Force Blue Ribbon Panel on Space recently reported that Air Force involvement in space will continue to grow and that the DoD has established "an irreversible military dependence on space systems based on exploding technologies."[4] These types of conclusions and countering arguments add to the difficulty of realistically assessing space and its potential impacts but do a lot to provide balance in this type of nonlinear assessment. Can a conclusion be drawn from the above and can potential impacts be identified as a result of it? The answers to these questions demand a great deal of judgement, experience and vision. Like the fathers of the Air Force, the visions of Generals Skantze, Herres and Piotrowski will eventually come to being. The real question is when?

There are other nonlinear relationships important to this study. One is the relationship of the nation's leadership and future space policy. President Kennedy perhaps more than any president provided an example of how important this relationship can be. Determined to engage the hearts and minds of America and demonstrate our nation's resolve to compete in space, he, in a very short time, lead our country with his vision farther and faster than most thought possible. The same potential exists today. Our national leadership is committed to the conquest of the final frontier and will remain so. This can only logically lead to the predicatory outcomes that are limited only by technology. Technology and policy form another nonlinear relationship with almost unlimited potential for impact. Given the political resolve to use our high-technology as leverage in the face of adversity, we not only foster synergistic effects but grow more and more reliant on space. The impacts then only become questionable in respect to when they will happen. Again, the lock-step, interdependent and linear nature of technology and its employment provides the answers to when.

The next element of the nonlinear assessment is the codification of the elements in the analytical framework (Chapter I, Figure 2). Impact on Air Force Civil Engineering is the object of the analytical framework. Which elements acting on the objective create the most potential for change? Like many relationship models this can be represented in a diagram. Keeping with the notion that the four major areas of the analysis form the elements of space with greater potential to reveal impacts than others, then it follows that they relate to the object and also interrelate to each other. Conceptually, the width of the lines in Figure 2 can be redrawn to represent the value of impact they present (Figure 10) with the widest line representing the greatest potential impact. For example technology and systems are linked strongly to support concepts which projects the widest line or greatest impact on civil engineering. This is due to the emerging technologies of support concepts. The direct requirement to operate in space, the rapidly developing body of space engineering and construction knowledge, and a national program to deploy a space station with military utility all provide additional support for characterizing the relationship of support concepts on civil engineering as the strongest. Tracing back from support concepts to engineering, Figure 10 shows a nonlinear or indirect relationship to National Space Policy and NASA activities in the area of developing large complex structures. Continuing on in the framework, the relationship of large structures such as a space station is tangent to activities associated with developing space power. This tangential type of relationship indicates a very close situation for the two activities. Taking the example one step farther, the development of power as a NASA activity is linked to power as an element of technology and systems which is further connected to space engineering and space facilities as elements of support concepts. While it is obvious that all elements are connected at the major area level, it is the smaller lines of the diagram, that depict the nonlinear or indirect relations that provide support to the assessment that certain aspects tend to impact on civil engineering in a synergistic manner.

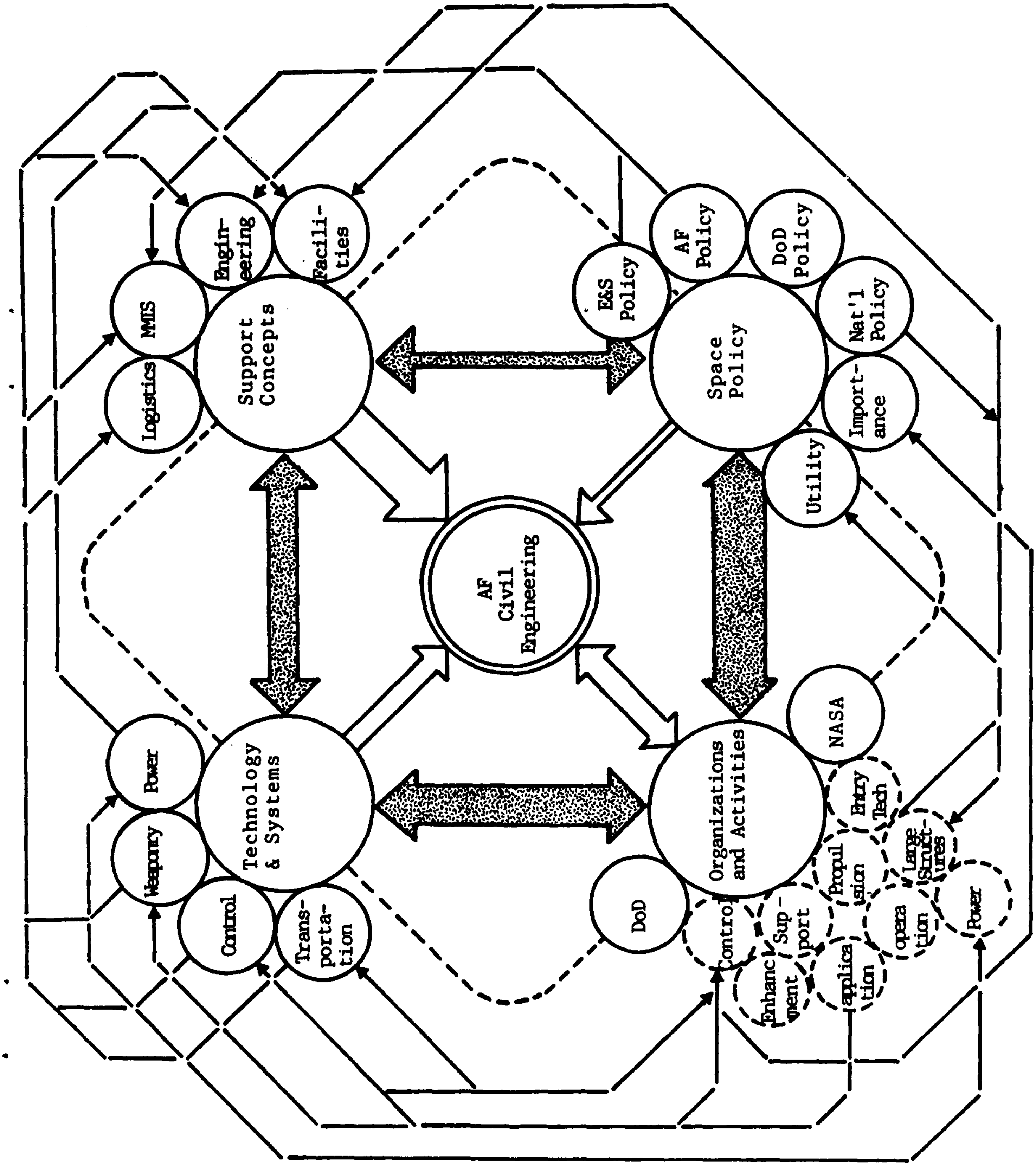

Figure 10. Codified Analytical Framework

As with the discussion on linear relationships, the lines in Figure 10 represent 33 nonlinear relationships and a separate discussion on each is beyond the intent of this study. It is important, however, to understand as Figure 10 indicates that the four major areas of the analysis interact with each other, and have subelements that have complex nonlinear relationships which taken as a whole, tend to create synergistic effects. These complex and mutually reinforcing elements account for the statements of visionaries who suggest that, space is achieving a critical mass that, space is a function of a set of converging influences, or that an irreversible dependence on space systems based on exploding technologies has been established in the military.

At this point in the assessment, it is useful to present an idea of how these linear and nonlinear relationships come together to create a probable future from which more specific impacts and recommendations can be drawn.

SYNTHESIS OF RELATIONSHIPS

It is possible, based on what has been presented, that the Air Force will by the year 2010 be actively involved in the construction of many large complex structures in space, all of which have a specific utility related to space control as a function of global dominance and power. This construction effort would include manned and unmanned platforms linked together in constellations with ORU maintenance nodes using advanced OMVs, OTVs and nuclear power centers. NDVs will routinely deliver specialist crews and materials from three or four air bases on earth. Large complex mission preparation hangars at these bases will have assembly lines to prepare the containerized payloads for each sortie to space with missions leaving several times each week. Space engineering will be a developed science as a result of over 10 years of zero- and micro-gravity research. In another constellation, robots, robotic supervisors and space people will be operating a logistics node which has as its mission, the assimilation of materials, systems and components necessary for the construction of a lunar station. Crews will be delivering these materials to the moon on a weekly basis as assembly crews put together the first permanently manned lunar base on its surface.

The above scenario, 40 years ago could have been dismissed as simply the script for a Buck Rogers' comic, but not today. The technology, the resolve and the potential exists today to make this vision a reality in the next 20 years. The resultant impacts such a scenario offers for civil engineering are enormous and include the formulation of a cadre of space facility engineers and construction crews, the development and use of standardized space construction materials and methods, the establishment of space logistics systems and space based depots, almost routine familiarization with space suits, tools, and vehicles for large numbers of people, and many more impacts that could revolutionize facility engineering. Will it happen? It is easy to imagine such scenarios and space advocates and visionary leaders have done so for decades. It is much more difficult to present a vision and the enabling set of capabilities necessary to make the vision a reality. It is even more difficult to speculate about the resources and political support needed to underwrite such a scenario. Suffice it to say, however, that such a situation is possible and perhaps probable given what this study presents. Space is mankind's final frontier and like all frontiers man will eventually preside in it.

In concluding this chapter, two important concepts need to be restated. First the linear relationships and the resulting characterizations of the major areas of this study bound the future impacts of space between a highly evolutionary bottom limit and a revolutionary upper limit. What this really suggests is that space will not impact civil engineering in moderately evolutionary ways. Second, nonlinear relationships support the claims of visionary leaders in space and suggest that many of the potential impacts space may have on civil engineering will come through the broad area of space support concepts. These support concepts are functions of complex networks linking policy, technology and organizations together in ways that create effects greater than the simple compilation of their individual parts. These two important concepts will form the foundation for the study's concluding recommendations.

NOTES

1. The original problem statement which this study responds to is "Unanticipated civil engineering support requirements for new missions in the Air Force, such as the introduction of intercontinental ballistic missiles, and ground launched cruise missiles have caused unplanned and dramatic changes in the missions and organization Air Force Civil Engineering. The advent of space operations may pose similar impacts, especially if revolutionary advances are made in the nature of launch and orbiting vehicles. Conversely evolutionary development in space operations may have only a minor impact or be limited to a small element of Air Force Civil Engineering. This study will determine by analysis and assessment the probable bounded impacts of space operations on Air Force Civil Engineering through the Year 2008." AUFORM 555, 1 September 1988, Lt Col John W. Mogge, Jr.
2. Maj Gen George E. Ellis, Briefing to Space 88 Conference, August 1988.
3. General Skantze, Military Space: A New ERA for Force Structure Decisions, p. 205.
4. Ulsamer, The Military Man in Space, p. 92.
5. Gen. Piotrowski, Space Evolution, p. 27.
6. Report USAF Blue Ribbon Panel on Space, November 1988.

CHAPTER VII
FUTURE CONSIDERATIONS

The assessment in the preceding chapter can be considered definitive from a macro viewpoint. The value of such an assessment is not so much in the vision it presents, but in the way the elements of the vision come together. One may construct any number of visions with the information presented in the analytical chapters of the study, and each vision would probably be judged as valid as the next. The relationships of the various elements and subelements, however, act in much narrower ways. By understanding how the various components relate, influence and impact each other, a more comprehensive understanding of the potential impacts of space on civil engineering can be achieved. It is this understanding that should serve the future leaders of civil engineering and result in their actions that guide the career field in its involvement in space.

Space, as the next frontier, is here. How Air Force Civil Engineering chooses to invest itself in space can be proactive or reactive. This study bounds the impact of space on civil engineering in the range of highly evolutionary to revolutionary, and suggests that many nonlinear relationships exist between elements involved in space that can come together to produce unanticipated and, in some cases, even dramatic impacts to the status quo. The dynamic relationships of space policy and technology may prove to be such a nonlinear determinant. On the other hand, there exists, what one may call "flag-waving advocates," who's judgement and vision are clouded with emotion. One sure way to divest itself of that type of influence is to constantly search the relationships of space policy, organizational activities, technology and support concepts for the impacts they may suggest. Additionally, Air Force civil engineers should adopt a set of approaches to space that form the basis of policy and long-term involvement designed to insure its ability to continue to execute its mission and guarantee its long term health. One such set of proactive approaches follows.

The first tenet of the set is to visualize the trend of the United States and the Soviet Union to turn toward space as their basis for global power. In doing this, civil engineers should see the space control mission clearly and start developing their roles in support of that mission. Civil engineers should understand that the distinctions between war and peace are different in space and consequently focus on their warrior roles early. Civil engineers should see space from a warrior's perspective and develop ways to exploit its efficiencies in combat. Civil engineers should establish their linkage to the weapon systems of space early as they have with war planes today.

The second tenet of the set is to focus attention on the linkages between space policy and space technology. As indicated the relationships of these areas have the potential to impact in dramatic ways. In doing this, civil engineers should continually stay abreast of developments in technology. This approach should be a broad-based effort with linkage to every space related research and development activity. This should necessarily lead towards moving space out of its very narrow channel in civil engineering and help develop a better understanding of the unique space force structure/facility relationship. Civil engineers should establish liaison contacts with NASA activities involved in space station research, space flight and science and technology research involving any type of future space facility as a means to generate early information about mission support requirements. Civil engineers should develop specialized focuses on space power, logistics, facilities and military men in space missions. Lastly, civil engineers should learn from the late start of space logisticians and develop ways to utilize space logistics technologies and coopt such technologies for their missions.

The third tenet is to accept a bias for action for space as a civil engineering frontier. One such action is to recognize the unique role of the communicators in space. Civil engineers should develop new understandings of those roles and respond to the need to develop specialty areas skilled in current and future operations involving knowledge systems, high-tech supportability, power and connectivity. Civil engineers should accept the premise that while space is not an exclusive club, the Air Force has been the service leader in space for over 30 years and will continue to be so. As such, civil engineers should take a leadership role in the design and construction of all future military space facilities. Civil engineers should fashion a space policy that establishes this space construction agent role firmly in the DoD. In addition to this military construction agent role, civil engineers should seek to establish a space corps with a specialized mission in space parallel to that of the Corps of Engineers civil works districts on earth.

The fourth, and last, tenet is to normalize and specialize space where appropriate in civil engineering. This could start by continually redefining space in terms of the traditional. Parallel with the logistics community, the civil engineers should attempt to normalize space by reducing it to routine functions. This might be brought about by the development of dual hatted astronauts who perform space facility engineering missions once in space. Civil engineers should build a cadre of space facility engineers specially trained in the provision, operation and sustainment of space-based facilities. Civil engineers should develop a program to channel and guide the current graduates of the Space Facilities Master's Degree Program at the Air Force Institute of Technology (AFIT) and the engineering graduates of the Manned Space Flight Engineer Course so that they spread their knowledge and help normalize the career field to space. Civil engineers should expand the narrowly focused space clearinghouse in AFSPACECOM by reestablishing the clearinghouse at the Air Force Engineering and Services Center (AFESC). Expanding and centralizing the clearinghouse function at a common center would increase the contacts available to the clearinghouse, divest it of its major command bias and allow other MAJCOMs and systems divisions more direct involvement in resource issues. Further, it would tend to stimulate an up/down flow of information and senior leadership involvement all of which is essential to truly normalize space in civil engineering. Civil engineers should begin developing operational bridges to space parallel with space requirements and technology. This can be done by strengthening all engineers' knowledge of space in entry, middle and senior continuing professional education courses at AFIT. Last, and in keeping with the third tenet, civil engineers should act in visionary ways. As space support concepts and capabilities are developed, organizations should be changed to fully exploit those capabilities. If specialty capabilities are needed, dedicated organizations should be developed to support such requirements. In all, corporate commitment, broad involvement and vision should be the by-words of this tenet.

How civil engineering is impacted by space can be answered to some extent by outlining avenues of proaction for civil engineering in space. It is time for civil engineers to whole heartedly embrace space and find ways in which they can contribute to the development of the final frontier in support of national security. This type of attitude was recently described by General Piotrowski in an article entitled Space Leadership: Vision or Vanity. General Piotrowski said, "To explore space is a noble goal, but to preserve the national security, to protect US assets, to ensure the right of free passage and to safeguard future explorers is a solemn obligation. It is an unavoidable prerequisite to pursuing *more exciting* goals" (Signal, May 1988, p. 27).

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